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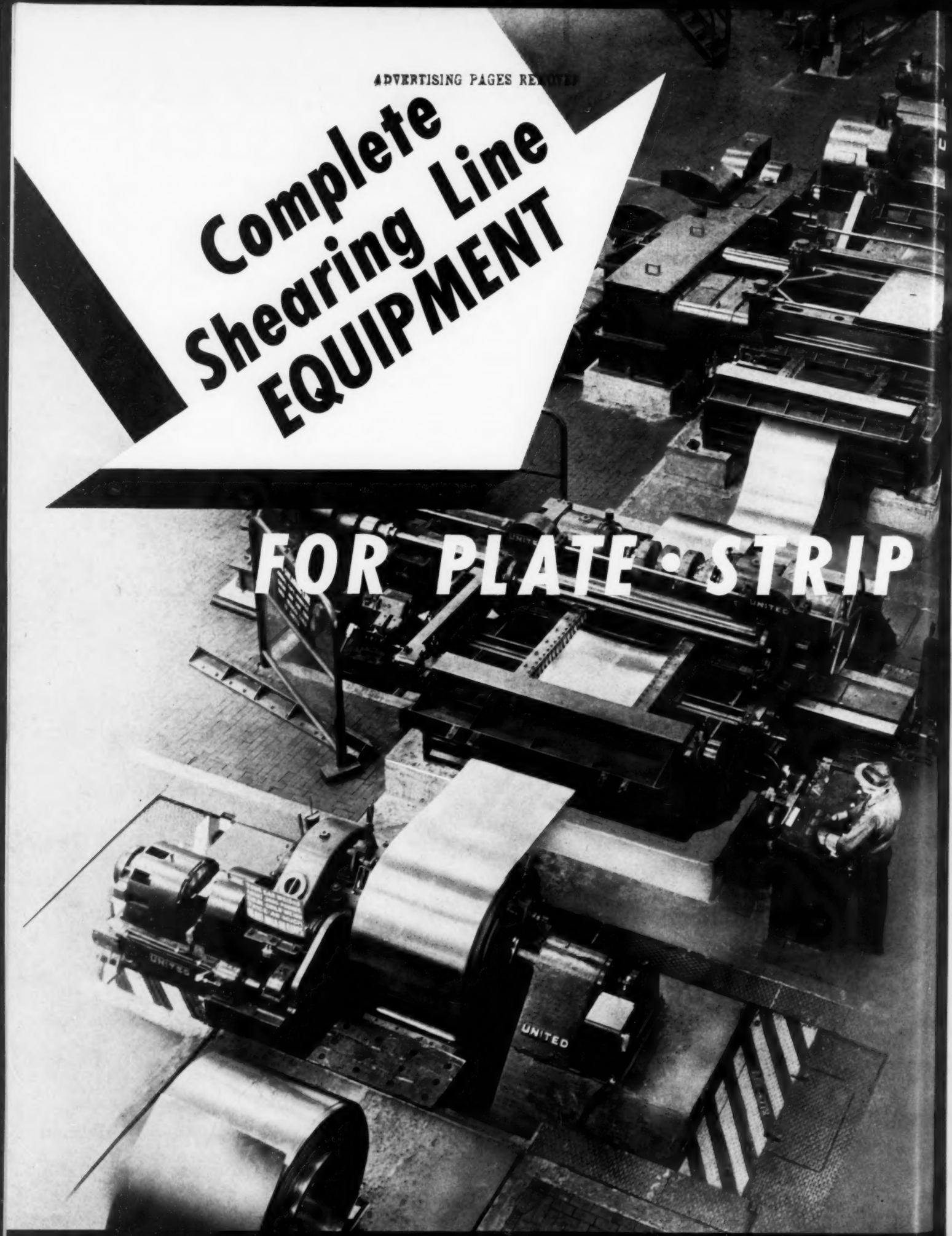

UNITED ENGINEERING *and* FOUNDRY COMPANY

Pittsburgh · Pennsylvania

Electric TRUCK Transportation in SHEET and STRIP Mills

By C. B. CROCKETT

Industrial Truck Statistical Association

CHICAGO, ILLINOIS

▲ BY way of an introduction to this paper the author wishes to disclaim any pretense to a knowledge of the steel business, so that if there is any value in the following material it may in part be derived from the fact that my observations are purely from the standpoint of a mechanical handling problem and with perhaps a blind disregard of the technology—yes, even the tradition—of steel production.

As may be noted from the title, we shall attempt to limit this discussion to the handling operations in connection with continuous sheet and strip mills and even closer to the use of electric industrial trucks in these operations, as any broadening beyond these boundaries would tax the limitations of both the time available and the author's knowledge.

BACKGROUND OF HANDLING

If, as we stated, we are to consider the handling operations in sheet and strip mills purely from the point of view of handling (and we shall soon see how impossible it is to separate them from the technical requirements of the production processes), we can first set down certain general questions which may be the basis for the study of any mechanical handling problem. Some of these are:

A. Material handled:
   1. What is the size, shape and weight of the unit to be handled?
   2. Is this unit uniform in relation to the above?
   3. Does it have to be handled in a certain position?
   4. Does it undergo any change in transit which affects the handling time required?
   5. What might be the effect of changes in the future?

B. Movement:
   1. Does the material always start from the same point?
   2. Does the material always go to the same destination?
   3. Does it move at a uniform rate of flow?

C. Production operations before and after handling:
   1. Does the operation preceding the handling deliver the material at a rate of flow greater than, equal to or less than the rate at which the material is consumed after the movement has taken place?
   2. Does the preceding operation deliver the material in the same position as is required by the operation following the handling?
   3. Are there any considerations of changes in rate of production in the future?
   4. Does the method selected take care of changes in production rates of both preceding and subsequent operations?

D. Plant layout:
   1. How far does the material have to be moved?
   2. What obstructions are to be encountered along the path of the movement?
   3. What areas along the path of the movement have to be kept clear?
   4. How adaptable is the method to changes in plant layout?

E. Other handling operations:
   1. Does the equipment selected have to perform any other operation than the one under consideration?
   2. What is the effect of this other function upon the availability of the equipment for the function being studied?

Many of the above considerations will appear absurd in relation to a known problem, but any of them are liable to crop up in one or more places as one operation after another is studied. While some operations are comparatively simple and the selection of the best type of equipment is obvious, there are others, probably in

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Pittsburgh, Pennsylvania, September 26-29, 1939

the majority, where various factors, some favorable and some unfavorable, have to be weighed and considered before a selection is made.

The simplest theoretical handling problem would probably be one where a uniform material, kept in the same position, moved at a uniform rate always between the same fixed points and where no obstructions were encountered, no areas along the path had to be kept clear, and there was no possibility of future changes in layout, production rate or unit to be handled. Such operations are not uncommon and it is obvious that a gravity conveyor of some type will prove to be the economical solution. The number of such conveyors in continuous mills is an example of the proper solution of the simpler type of operation.

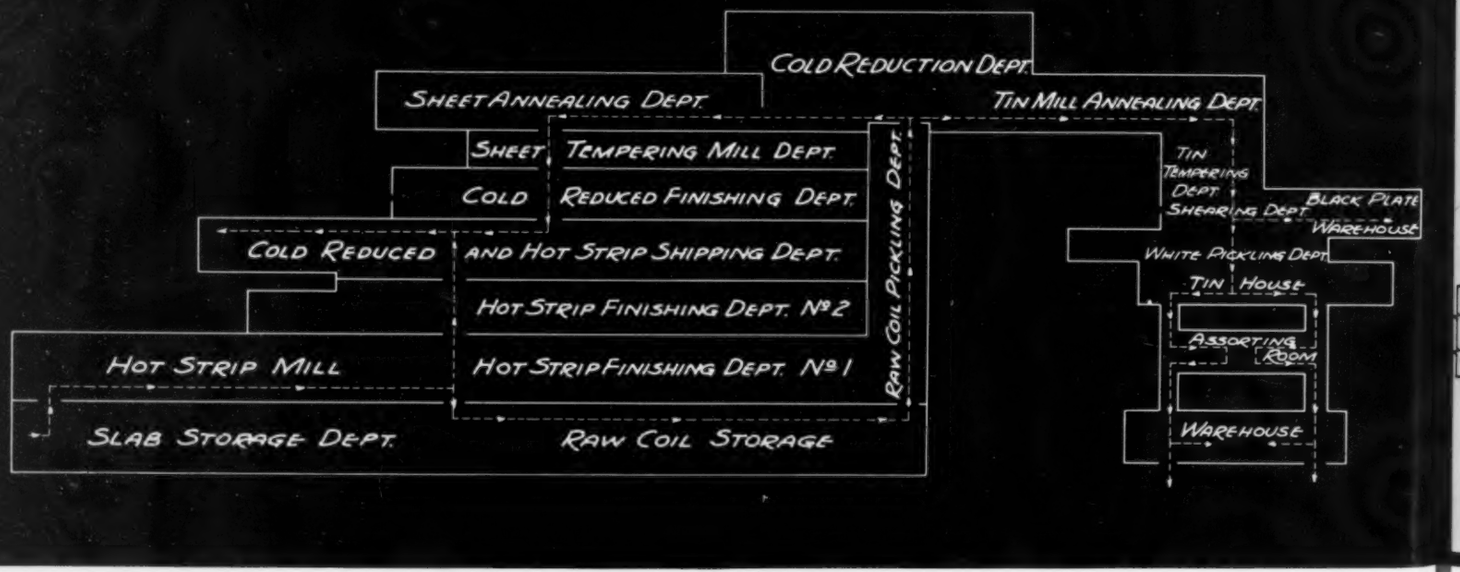
On the other hand, taking one of the foregoing conditions, such as E-2, we may find that an overhead crane may be available for a production handling operation 98 per cent of the time. However, this same crane was installed to handle maintenance work on a certain piece of equipment. Obviously the crane cannot be in two places at the same time and the natural result is that an entire production line may have to shut down because the handling equipment is otherwise engaged.

This leads us to a discussion of the principal handling operations in continuous sheet and strip mills, and again I want to repeat that I am not a steel man nor prepared to answer questions regarding general layouts. From a material handling standpoint, however, the mills visited follow the general principle of straight line production. And where we speak of straight line production it should be noted that this does not mean that all, or in fact, any two major movements of material have to be in the same straight line or even in the same direction. From a handling standpoint it is just as easy and just as economical to have one movement 1000 ft. east and the next 1000 ft. west, as it is to have them both in a continuous line of 2000 ft. east. "Back tracking" is sometimes referred to as a thing to be avoided, but by "back tracking" I think reference is made to the movement of material back over a considerable distance before the next productive operation can be performed. The essential of good layout is to have the start of a productive operation as near as possible to the end of the preceding operation. In fact much of the movement in these mills, where the material is not being worked, is at right angles to the production flow itself, as will be seen from the diagrammatic layouts in Figures 1 and 2.

It should also be remembered that though the name continuous is applied to these mills the reference is really made to the rolling operations themselves, and the handling operations are of the unit type. It is with units either in the form of coils, or sheet in stacks that we are concerned. Furthermore, I believe special consideration should be given to the future trends or the present trend in the size of these units. Starting with coils weighing about 6000 lb., the trend has been to coils of 12,000—15,000—18,000—24,000 lb. each, and coils of 36,000 lb. and higher are under contemplation. How far this increase will continue it will be up to the steel industry to say. Equipment manufacturers such as truck (or tractor, as they are sometimes termed) builders are prepared and have built machines whose capacities seemed impossible a few years ago, but along with these huge machines will come higher investments, higher operating costs, greater space requirements and a certain slowing down of the truck operation due to the great weights. These will be offset by lower labor cost, but of course, the reason for the bigger coils is to be found in the rolling rather than the handling operations.

CHOICE OF EQUIPMENT

In general it may be said that there are three types of equipment widely used in continuous mills: cranes, conveyors and trucks or tractors. To provide the necessary background for the truck and tractor operations,



it seems wise to show how each type of equipment has been applied.

First, cranes: nearly every major bay is equipped with a crane, sometimes two or three. The capacity of the crane is generally determined by the maximum lift to be made for any piece of equipment served by that crane. Thus, many cranes are really too large to do any routine production handling of material. Second, crane handling nearly always requires one or two men on the floor in addition to the crane operator. Now it may be one thing to laugh off an additional man or two in a plant operating say 40 hours per week, but let us see in dollars and cents what it means on the basis of 20 turns a week for say 50 weeks, which I admit is a pretty high rate of operation. At 60 cents an hour, this would amount to $4,800 per year additional labor cost, and if it were general policy that an investment in equipment should be written off in 5 years, it would then be possible to invest $24,000 in equipment in order to release one man for productive work. Cranes, of course, are limited in the area they can serve and, as one steel man said, they have never found any good way of letting cranes pass each other on the same runway.

Conveyors are of two general types: first, the short section of roller conveyor used for transfer from one bay to an adjoining one or at the feed or discharge end of a mill, shear, or other production equipment. Here the conveyor serves a useful purpose in providing storage for a cushion stock, thus making the material handling equipment feeding that stock independent of the momentary requirements of a given piece of equipment. Second, there are a number of long power driven conveyors, particularly at the end of the hot mills conveying hot coiled strip to raw coil storage or to the pickling line. Here the conditions point to a conveyor for the movement is always between the same points and the coils are given time to cool while in transit. The greatest difficulty encountered with conveyor installations is to be found in the obstruction they form in parts of the mill which it is desirable to keep clear and in the variety of flow of material once it has entered the cold mill department.

After such a lengthy introduction, therefore, we come to the heart of this discussion, the operations performed by electric trucks and tractors and the equipment developed for this purpose. Taking a composite of the mills visited we find the following operations performed by truck:

Material	*From*	*To*
Coils	Raw coil storage	Hot strip finishing and shipping department
Coils	Pickler	Cold mills
Coils	Cold mill	Scrubber or electrolytic cleaner
Coils	Cleaner	Annealing
Coils	Annealing	Storage
Coils	Storage	Tempering mills
Coils	Tempering mills	Shearing lines
Sheet	Shearing lines	Annealing
Sheet	Annealing	Tempering mills
Tin plate	Shearing lines	White pickler
Tin plate (in bosh tanks)	White pickler	Tin house
Tin plate	Tin house	Assorting room
Tin plate	Assorting room	Warehouse
Tin plate	Warehouse	Shipping
Black plate	Shearing lines	Warehouse
Black plate	Warehouse	Shipping

Under the best conditions of layout, most coil movement can be limited to runs of 100 to 300 ft. one way

FIGURE 1—Diagram of arrangement of departments and flow of material in typical strip mill. (opposite page)

FIGURE 2—Diagram of arrangement of departments and flow of material in a finishing department. (below)

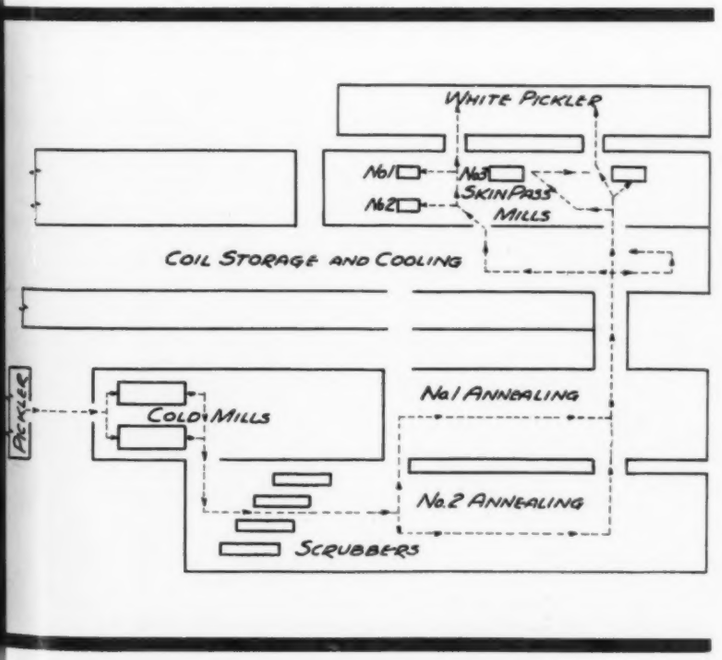


FIGURE 3—Two coils may be handled simultaneously by the twin forks on this unit.

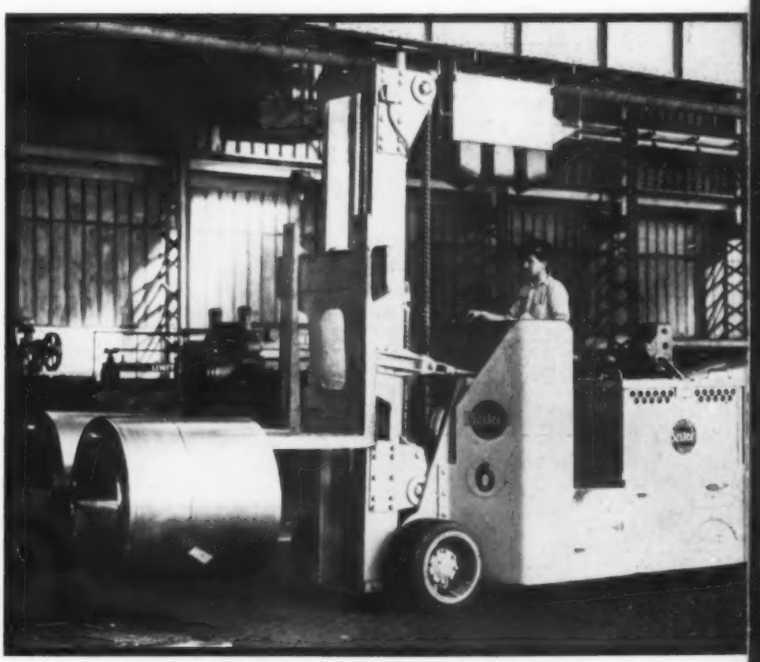


TABLE I

Operation	Approximate distance, one way (ft.)	Equipment
Raw coil storage to hot strip shipping	300	3—15,000 lb. Ram
Pickler to 3-stand tandem mill	150	1—15,000 lb. Ram
Pickler to reversing	150	
Pickler to 5-stand tandem	150	1—15,000 lb. Ram
Delivery from 3 mills to shearing lines and electrolytic cleaners	400	2—15,000 lb. Ram
Feeding 3 shearing lines	100 to 300	1—15,000 lb. Ram
Shearing delivery to transfer car	75	1—15,000 lb. Fork
Electrolytic cleaner to transfer car	75	1—15,000 lb. Fork
Annealed coil storage to 3 skin mills	100	2—15,000 lb. Ram
Skin mills to shearing lines	50	1—15,000 lb. Ram
TIN PLATE		
Shearing lines to white pickle	250	2—20,000 lb. Carrier trucks
White pickle to tinning machines	300	3— 7,000 lb. Bosh tank trucks
In tin house	200	1— 3,000 lb. Fork
Tin house to assorting room	600	3— 4,000 lb. Fork
In assorting room	200	1— 4,000 lb. Fork
Assorting room to warehouse	500	3—10,000 lb.—117 in. Telescoping fork
		1— 3,000 lb. Fork
Loading platform—warehouse to cars	200	3— 4,000 lb. Fork
BLACK PLATE		
Shearing lines to warehouse	400	1— 6,000 lb. Fork
Black plate warehouse to shipping platform	250	1— 7,000 lb. Telescoping fork
		3— 4,000 lb. Fork
MISCELLANEOUS		
Metal, middlings, palm oil, storage	...	1— 6,000 lb. Low lift

TABLE II

	Feeder end tandem mill	Flying shear	Continuous pickler	Finishing end tandem mill	Skin mill and flying shears	Hot mill 60 in. combination shear
Total number hours studied	26.33	24	23.58	33.67	35.33	44.67
Actual hours truck in operation	15.07	16	16.46	..	..	17.617
Per cent in operation	68	66.7	69.8	..	..	48
Mill production—coils (not actual handling)	441	326	421	434	..	272
Tons	1401	852	1308	1619	..	453
Truck miles travel	29	27	27	..	35	41
Ram travel (ft.)	4680	3131	3993	..	4967	4047

TABLE III

	Feed tandem mills	Flying shears	Continuous pickler	Finishing tandem mills	Flying shear and skin mill	Hot mill combination shear
Number coils handled	441	400	445	434	..	272
Average weight	6360	5862	6340	7500	..	3330
Average ram travel per coil (ft.)	10.62	7.82	8.96	..	..	15.4
Average truck travel per coil (ft.)	347	354	317	..	..	793
Average ft. per hr. travel	5842	5896	6000	..	5214	4836
Average ft. per hr. ram	178	130	169	..	140	101
Average kwh. per hr.	3.72	3.45	3.38	..	2.68	2.27

or round trips of 200 to 600 ft. With present mill capacities and other equipment such as shears, picklers, etc., and with trucks of 15,000 lb. capacity, one truck can generally serve a machine with either incoming or outgoing material provided the length of run loaded is not more than 150 to 200 feet.

EQUIPMENT REQUIRED

For example in one mill the lengths of run (one way), and the number of trucks, was found to be as shown in Table I.

Production, layout, type of material rolled, etc., will all have an effect on figures of tonnage handled as will also the length of haul. Certain studies, however, may be of general interest and to illustrate the really tremendous amount of material handled by one of these machines, Table II is offered.

For those who are interested in unit figures of work performed per hour Table III is given.

As coil sizes are constantly increasing it may be of interest to examine the power consumption of these trucks in relation to the size of the coil in order to see what problems will be faced as coil sizes are further increased. The average ampere discharge on the truck lift and travel varies with coil weight somewhat as follows:

Coil, lb.	*Travel, amps.*	*Lift, amps.*
Light	137.5	52
2,000	139.5	57.5
4,000	142.1	63.0
6,000	145.0	70.0
8,000	148.0	77.5
10,000	152.0	85
12,000	157	92
14,000	162	98

As might be expected, the power required for truck movement does not increase in any way as fast as the load increases. In fact, a 100 per cent increase in the pay load from 6000 lb. coils to 12,000 lb. coils required only 11 per cent more power for horizontal movement. Power for lifting the ram does, of course, increase more nearly in proportion to the increased load though even here the figure for the increase from 6000 lb. to 12,000 lb. coils is only 32 per cent.

It is reasonable to assume, therefore, that the power required or power costs per ton or ton-mile will be further reduced by further increases in the size of coils handled. As the same operator will be employed the labor cost will be reduced in direct proportion to the increased load and there will be a further reduction in the form of fewer trips.

However, there are two sides to every question and the writer wishes to point out one interesting case in one of the plants visited. In the movement of tin plate from the tin house to the assorting room three 4000 lb. fork trucks are employed with an average run of 600 ft., one way. The combined capacity of these three trucks is only 12,000 lb. or less than that of one of the large ram trucks and yet these trucks can handle the same flow of material on a 600 ft. run that taxes the capacity of a 15,000 lb. truck on a 200–250 ft. run. True, the labor cost is three times as high for the three drivers of the small trucks and there are other reasons for the smaller unit loads such as variation in the delivery point but the point is that equal tonnage when broken into smaller lots can be handled faster (not more cheaply) by the smaller machine.

I believe I am safe in saying that there has been more fundamental improvement in truck design since 1932 than in the entire previous history of the industry. Limiting our comments to the type of truck common in steel mill service, there are probably three or four major developments of the greatest significance. First, (and these are not in the order of importance, for each is like the leg of a three-legged stool) is center control. The

FIGURE 4—Power driven conveyors on trucks afford added flexibility of application.

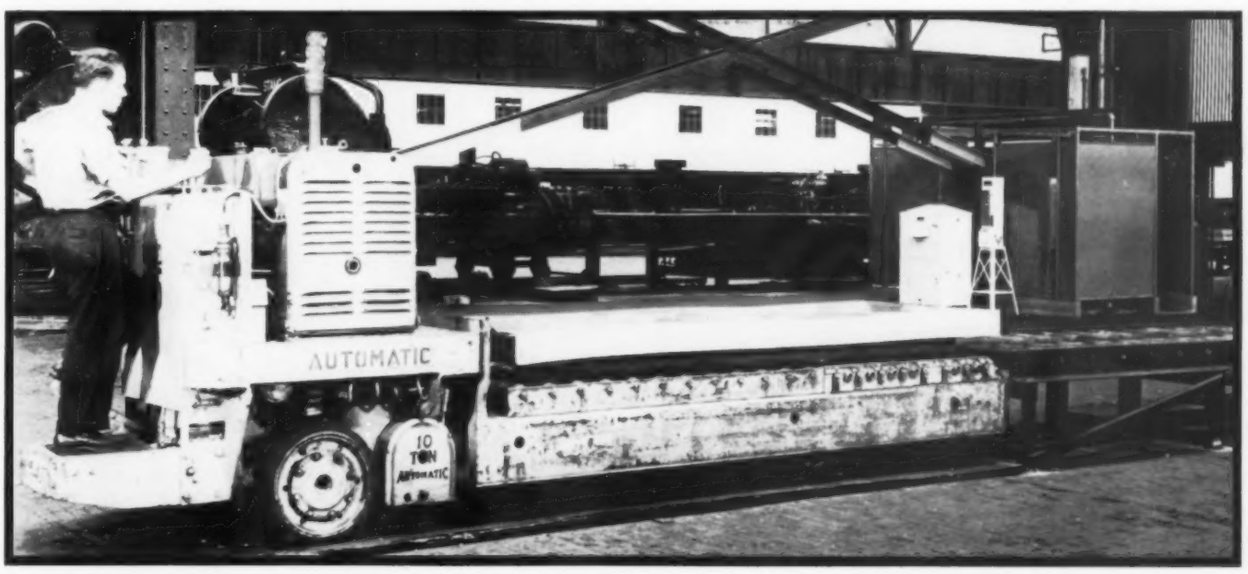


FIGURE 5—View showing comparison of 25,000 lb. ram truck with a 2500 lb. truck of ten years ago.

placing of the operator at the center of the machine has:

1. Reduced overall length.
2. Greatly increased visibility.
3. Reduced maneuvering space required.
4. Allowed the placing of counter weights where they are most effective.

FIGURE 6—This ram truck, handling coils, operates in a constricted area.

5. Affords protection for the operator.
6. Permits the use of maximum sized batteries.

Second, the introduction of power steering devices. As capacities increased it became obvious that to maintain maneuvering speed and overall efficiency, hand steering was becoming obsolete. Today these steering devices have become so perfected that the operator of a truck of 20,000 lb. capacity can place his machine in the exact location required with the same ease and speed that we had become accustomed to with the 4000 lb. truck.

Third, the development of controls in keeping with the tremendous weights and power requirements of these tremendous trucks. This has been accomplished through the development of automatic accelerating controls with time delay non-plugging relays usually in four steps. Many of you can imagine the effect on tires, shafts, gearing, etc., as well as electrical loads if when running full speed ahead, an old type controller were to be thrown into full speed reverse and truck operators are no different from the people in the cartoons—"They'll do it every time!" With the most modern controller, however, when such an act of mechanical suicide is committed the truck comes to a gradual stop, reverses and picks up gradually through the proper speeds in reverse. Along with this type of controller, has come electric braking on the lowering of the ram with adjustments of the resistance for varying loads and speeds.

Fourth, is the development of storage batteries having ample capacities for the operation of these trucks under the severest production requirements.

Material handling is no longer considered apart from the production operations. Handling costs must be

viewed in conjunction with overall production costs. The cheapest handling method is that which permits operation at maximum capacity, and in attaining this end the electric industrial truck has proven of vital assistance.

DISCUSSION

PRESENTED BY

F. O. SCHNURE, *Electrical Superintendent*, Bethlehem Steel Company, Sparrows Point, Maryland.

C. B. CROCKETT, Industrial Truck Statistical Association, Chicago, Illinois.

D. W. DEAN, Rectox Section, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

W. VAN C. BRANDT, *Manager*, Motive Power Battery Sales, Electric Storage Battery Company, Philadelphia, Pennsylvania.

F. O. SCHNURE: I would like to ask Mr. Crockett if, in his travels around the country, he has accumulated any information regarding the cost of the various components entering into truck transportation?

C. B. CROCKETT: I haven't any figures, to answer Mr. Schnure's question directly—that is, where these costs have been reduced to unit figures of cost per ton. I have, however, some figures on the operating cost of fleets.

For example, at one plant operating three trucks in sheet and tin mill operation, the cost of the trucks was $3500 a year. That is a little more than $1000 a year, exclusive of the wages of the drivers and exclusive of the power. In this particular case the power costs were something under one cent a kilowatt hour.

In another plant there were six 12,000 lb. ram trucks, which had a total cost of $9100 or $1520 per year. That is the large capacity, 12,000 lb. ram truck, and included repair parts, labor, tires, batteries.

I did find a tremendous variation in cost due to the conditions under which the machines were operating and the age of the equipment. I have been inclined to think I saw some machines where the repair parts had run up as high as $1000 a year. That isn't the important part of the problem. The important part is what effect that truck operation has on the production records in that mill, because if those trucks are undergoing repair all the time it must have a disadvantageous effect on the production record in the mill. I saw other operations, where the trucks were a little bit newer, where the cost under an exactly similar operation was less than one-eighth of the cost in the first mill.

I think that is a point that should be taken into consideration. It isn't the cost of the equipment itself, if by replacing that equipment you can get a greater production in your own operation.

W. VAN C. BRANDT: Having followed the development of the electric industrial truck for the past 25 years, it has been quite interesting to note the rapid development in the past four or five years.

Twenty-five years ago, the electric industrial truck was considered a supplementary piece of handling equipment. The trucks were usually small, of about two ton capacity, and principally load carrying trucks, followed later by the low lift type. The general public's conception of the electric industrial truck was that of the baggage truck used around railroad stations for hauling baggage or express matter.

Today the electric industrial truck is a production unit just as important as any of the production machinery and when a truck breaks down production is held up. Tremendously large plants have been built in recent years around the truck as a material handling unit.

The development in styles and types in the last five years has been most interesting. Today we have trucks of a size and type never dreamed of a few years ago. Electric trucks capable of picking up, elevating and hauling 25,000 lb. coils of steel are being built, and we are thinking of 30,000 lb. ram trucks, and I don't believe it will be very far in the future before 50,000 lb. ram trucks will be in general use.

The battery industry has not only tried to keep pace but to lead the development, and the development and construction of huge batteries has in no small extent been responsible and of assistance in the development of the larger types of trucks which are today available.

Some years ago, the average size battery for an industrial truck had a capacity of approximately 300 to 350 ampere hours. With an increase of 50 per cent in the plate height came what was then called the "high type" cell with 500 to 600 ampere hours capacity. A few years ago we thought these were big batteries, but in the past few years we have developed even larger ones and today industrial truck batteries of a thousand ampere hours are available, and it will not be difficult to extend this development to a battery of 2000 ampere hours if necessary.

Another interesting development has been that of steel trays which have made their appearance within the past two years. Steel trays enable the assembly of up to as much as 34 per cent additional ampere hour capacity and batteries of 20 per cent greater voltage in the same space formerly occupied by batteries in the wood tray construction.

The progress that has been made in the industrial truck industry during the past several years shows promise of even greater and more interesting developments in the future, and to a certain extent the progress made in building these huge super trucks of today has been in a way directly connected to the developments in the steel industry. For instance, a few years ago, at the Iron and Steel Engineers' Convention in Detroit, I had the pleasure of going through one of the large continuous rolling mills and following the manufacture of sheet steel from the open hearth furnace to the finished product. At that time, the coils of steel being rolled averaged about 6000 to 10,000 lb. Electric welding has changed this today so that coils can now be rolled that will weigh 20,000 to 25,000 lb. The building of huge ram trucks to a certain extent has made this possible because it was necessary to have some means of

handling these huge coils quickly and economically. There may be other problems that will limit the size of the coils to be rolled, but it seems one of the first limiting factors was the method of handling. If it is going to be of advantage to the industry to roll coils of 50,000 lb., I am sure the electric industrial truck industry will develop trucks to handle such loads, and the battery industry already has batteries of sufficient capacity to power such trucks.

After my visit to the steel mill, I followed the sheet steel through an automobile body plant and then an automobile plant, and it seemed to me that there was one step in this process that could be eliminated. I did not quite understand why it was necessary after the steel was rolled and coiled to have it uncoiled, cut up into sheets and shipped in packs, but rather why it was not shipped to the automobile body companies and other purchasers as coils. This would create a market for a number of ram trucks in the automobile industry. Since this time, I understand that some of the steel purchasers are now obtaining steel directly in coils rather than in sheet form.

Another particularly interesting development has been that of cost keeping. A few years ago there were very few large manufacturing concerns that kept any record of material handling cost at all and perhaps 95 per cent of the manufacturing concerns today lump their material handling cost into general factory overhead or production cost, but this is now changing, particularly in the steel industry, and many of the large steel companies are now beginning to get real facts on their material handling cost and are learning just what it costs them to run a truck, which, in my opinion, is essential for accurate control of material handling. Keeping cost records will enable manufacturing plants to determine definitely what is the most efficient size and type of material handling truck, as well as the most efficient and economical power supply for such trucks.

D. W. Dean: In connection with the question of cost that Mr. Schnure raised, I believe you gentlemen might be interested in the development of the static type battery charging equipment that supplements the type of equipment with which you may be more familiar. I refer to the copper-oxide rectifier.

Most of us are used to thinking of the copper-oxide rectifier as the small disk type that we have been familiar with in the past, which is capable of delivery of only a few amperes, but with the development of the plate type copper-oxide rectifier these capacities are now almost unlimited. In fact, we are now building a 2000-ampere, 12-volt rectifier for electrochemical purposes, and the rates involved in battery charges are quite practical with the static type battery charger. I do not think the copper-oxide battery chargers are going to compete with the larger rotating apparatus, where you have a centralized charging system of considerable kw. capacity, but where you have an isolated charging installation for two or three trucks the copper-oxide battery charger does have good economic possibilities, because it comes as a completely assembled unit, with no foundation required, and no wiring between the various units of the equipment. The rectifier can be just set down on the floor, the a-c. leads connected into it and the charging leads connected, and that is all there is to it.

It has another very good application, particularly in the steel industry, where your centralized charging equipment may be at one end of the plant and you have a truck working at another end of the plant. Possibly that battery capacity isn't sufficient to get through the day's run and you need a booster charge. It is foolish to run the truck back to the central charging equipment for the booster charge. Install a self-contained copper-oxide charger, down where the truck is doing the work, and give the truck a booster charge when it needs it.

Another case, other than the booster charge is where you have a truck that is working primarily at some distance from the centralized charging station. Why should it be necessary to run that truck back at night to where the central charging equipment is located? You can put in the copper-oxide charger right where that truck is doing its work and eliminate that travel back and forth to the centralized charger.

Annual Spring Conference

ASSOCIATION OF IRON AND STEEL ENGINEERS

HOTEL NETHERLAND PLAZA

CINCINNATI, OHIO

APRIL 1-2, 1940

TENTATIVE PROGRAM

MONDAY, APRIL 1

9:00 A.M.

"ELECTRICAL FEATURES OF THE ARMCO SLABBING MILL"
By A. F. Kenyon, Steel Mill Engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

"FACTORS TO BE CONSIDERED IN MODERNIZING EXISTING ROLLING MILLS"
By C. H. Hunt, Consulting Engineer, Pittsburgh, Pennsylvania.

"STRIP MILL FINISHING EQUIPMENT"
By D. A. McArthur, Chief Engineer, Wean Engineering Company, Warren, Ohio.

"WARD-LEONARD CONTROL FOR STRIP MILL AUXILIARY DRIVES"
By E. S. Murrah and H. W. Poole, Steel Mill Section, Industrial Department, General Electric Company, Schenectady, New York.

2:00 P.M.

INSPECTION TRIP: Andrews Steel Company, Newport, Kentucky.

6:15 P.M.

INFORMAL DINNER

8:00 P.M.

"IMPROVEMENTS IN OPEN HEARTH DESIGN AND OPERATION"
By L. F. Reinartz, Manager, Middletown Division, American Rolling Mill Company, Middletown, Ohio.

"PROBLEMS IN THE OPERATION OF WIDE STRIP MILLS"
By G. D. Tranter, General Superintendent, American Rolling Mill Company, Middletown, Ohio.

TUESDAY, APRIL 2

8:30 A.M.

INSPECTION TRIP: The entire day will be devoted to an inspection of the Hamilton and Middletown plants of the American Rolling Mill Company.

Please Make Early Reservations for All Activities
Address: Association of Iron and Steel Engineers
1010 Empire Building, Pittsburgh, Pa.

A DOUBLE BUS SYSTEM for Power Transmission

By D. I. BOHN, *Electrical Engineer*
ALUMINUM COMPANY OF AMERICA
PITTSBURGH, PENNSYLVANIA

and J. E. HOUSLEY, *Supt. of Power*
ALUMINUM COMPANY OF AMERICA
ALCOA, TENNESSEE

Presented before A. I. S. E. Annual Convention, Pittsburgh, Pennsylvania, September 26-29, 1939

▲ POWER transmission systems vary widely, principally in the extent to which flexibility of switching to meet all assumed conditions is carried. The Alcoa power system, comprised of 265,000 kva. of generation in three hydro-electric power developments, feeding a normal load of 200,000 kw. to the Alcoa aluminum plant, leans in the direction of simplicity.

The aluminum works at Alcoa, Tennessee, receives its power from a group of three plants, Cheoah, Santeetlah and Calderwood, located about 50 miles above the mouth of the Little Tennessee River, in the edge of the Great Smoky Mountains on both sides of the Tennessee-North Carolina line. The plan, Figure 1, shows that these plants are hydraulically, as well as electrically interconnected. The principal storage is provided by the Santeetlah plant, located on the Cheoah River, 10 miles above its mouth. The water stored in the Santeetlah Reservoir, which has a maximum elevation of 1817 ft. is used by all three plants through a total head of 1069 ft. without any loss of head. All these plants are similar; each consists essentially of a dam, tunnel, a surge tank, and a power house, although the details have been varied to suit the particular site and to take advantage of the progress in the art of hydro-electric design that has taken place during the period of their construction.

A double circuit, 3 phase, 150 kv., grounded neutral, steel tower transmission line 30 miles long connects the power plants to the substation at the Alcoa Works. All transformer banks are connected Y-delta and the neutrals are solidly grounded at each bank. The 500,000 c.m. conductors are of aluminum cable, stee reinforced. They are supported by 10-unit strings of suspension insulators. In the very rough country adjacent to the power plants, the conductors of each circuit are arranged horizontally on a separate steel tower line. In the relatively flat country adjacent to the

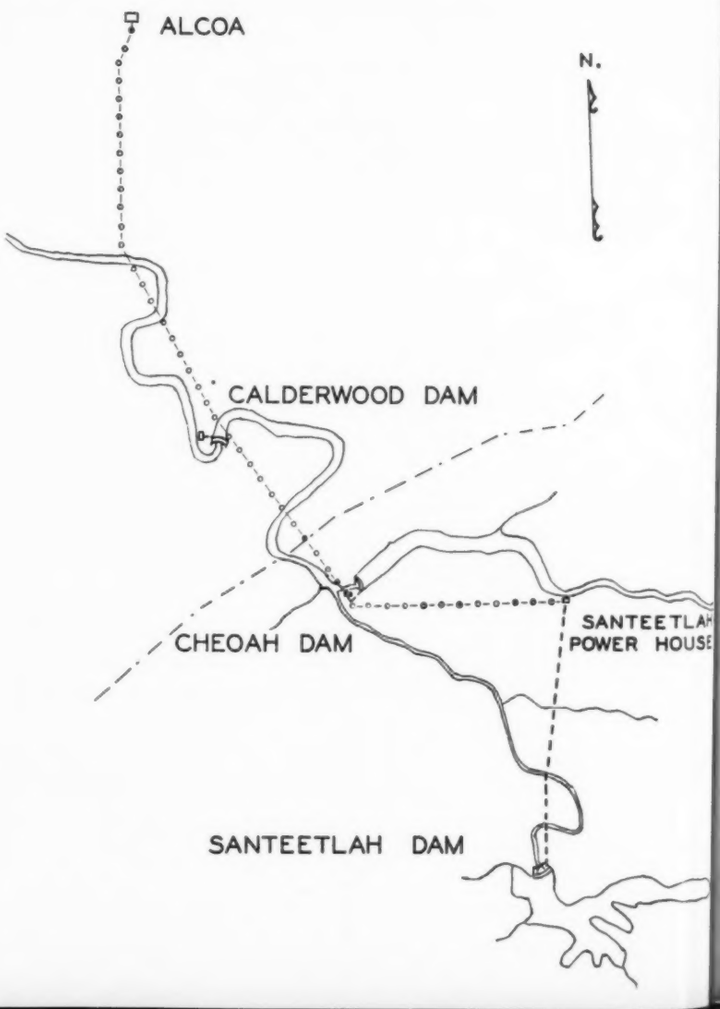


FIGURE 1—Plan showing locations of power plants supplying the Alcoa plant.

Alcoa plant both circuits are carried on a single tower line, with the conductors arranged vertically. There is one span nearly a mile long in the mountainous area.

The power system, as will be observed in Figure 2, is essentially in its electrical features a double bus system. Figure 3 shows in detail the one line diagram of this system and shows the extent of the double bus system and the unit layout system at the power plants. The system is interconnected with the Tennessee Valley Authority 154-kv. and 120-kv. systems at Alcoa.

Cheoah, the first of these plants, was completed early in 1919. It is in a narrow gorge on the main river just above the mouth of the Cheoah. The gravity type concrete dam, arched in plan, is 230 ft. high and 770 ft. long, measured along the crest. The drainage area above the dam is 1630 square miles. The reservoir is 7 miles long, has an area of 700 acres, and a useful storage of 7500 acre feet.

The Cheoah power house has four vertical units, each consisting of a turbine having a capacity of 27,000 hp. at 171½ rpm., designed for a maximum head of 190 ft., and taking 1575 cu. ft. per second at a normal operating head of 183 ft. The turbine is direct connected to a 3 phase, 60 cycle, 13,200 volt, 20,000 kva. generator having a 90 per cent power factor, with direct connected exciter and a pilot exciter. Each transformer bank consists of three 7000 kva., single phase, 13,200/154,000 volt, oil insulated, water cooled transformers. The usual complement of switches, meters and auxiliaries is provided for the convenient and flexible operation of the station. The Cheoah development lacks storage capacity to equalize the irregular flow of the river, and when operated alone produces widely varying amounts of power.

Santeetlah, the second development, completed early in 1928, was intended to supply this needed storage. The dam is located across the Cheoah River, 10 miles above its mouth. It forms a reservoir having an area of 2973 acres and a useful storage of 131,000 acre feet, sufficient to provide annual regulation for the drainage area of 175 square miles. The dam is concrete, 200 ft. high and 1150 ft. long along the crest. The central section is an arch 366 ft. long, abutting on each side against a gravity section designed to take arch thrusts in addition to direct water load.

The water is conducted from the dam to the surge tank through a five mile pressure conduit operating under a maximum head of 160 ft. This conduit consists of a series of five separate tunnels having an aggregate length of four miles, connected by steel pipes 11 ft. in diameter.

The Santeetlah power house is located on the margin of the reservoir five miles above the Cheoah dam. It contains two vertical units, each consisting of a 33,000 hp., 450 rpm., turbine, taking 550 cu. ft. per second of water under a maximum head of 660 ft. Ech turbine is direct connected to a 25,000 kva., 13 200 volt, 3 phase, 60 cycle generator, with direct connected exciter and pilot exciter. Two banks, each consisting of three 8333 kva., single phase, oil insulated, water cooled transformers step up the voltage to 150,000 volts. The necessary switches and other station auxiliaries are provided. This plant is operated generally during periods of low water to fill out the valleys in the power curve not only by generating power locally but also by increasing the flow of the Little Tennessee River for use at the Cheoah and Calderwood plants.

Early in 1930 the Calderwood development was completed on the Little Tennessee River, 9 miles downstream from the Cheoah plant. The dam is a concrete arch, 230 ft. high and 897 ft. along the crest.

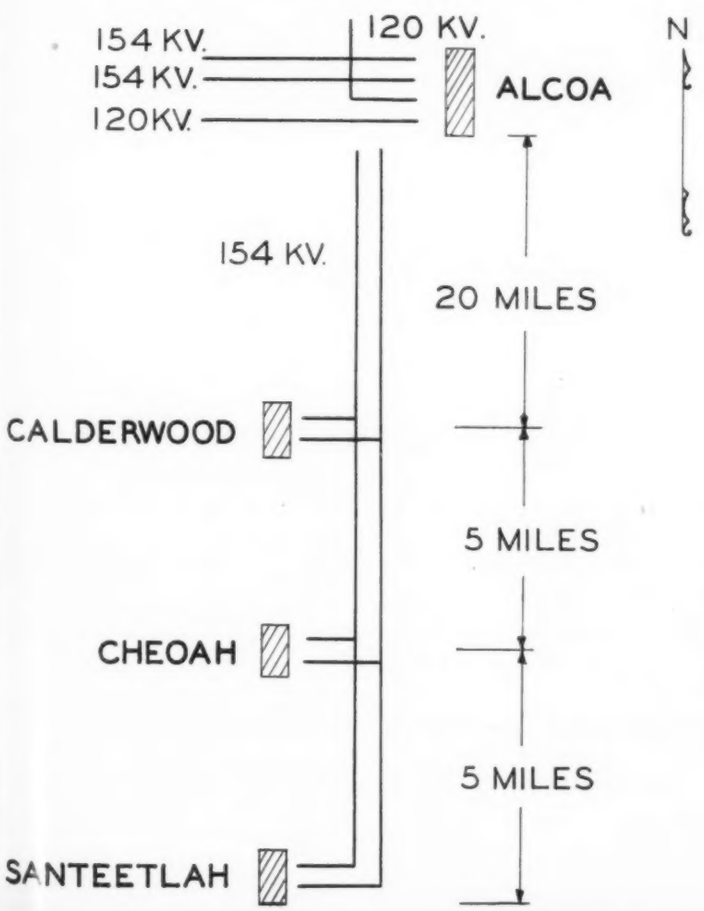
The Calderwood power house is crowded into a narrow space between the river and the cliff. It contains three units. Each unit consists of a vertical 56,000 hp., 150 rpm. turbine, operating under a maximum head of 220 ft. and taking 2500 cu. ft. per second under a normal operating head of 213 ft. Each turbine is direct connected to a 45,000 kva., 3 phase, 60 cycle, 13,200 volt generator with direct connected main and pilot exciters. Each unit is connected through oil and disconnecting switches directly to its bank of single phase transformers, which in turn are connected through high tension oil switches to the high tension bus. The bus may be sectionalized so that the station output can be sent out on one or both of the high tension circuits.

Cable strain buses are used for the high tension bus work wherever possible. Compression fittings are used exclusively on these buses and no contact troubles have been experienced.

The principal load at the Alcoa plant is the electrolytic reduction load served by forty-five 2500 kw. rotary converters and twenty 2750 kw. mercury arc rectifier tanks.

A large sheet rolling mill is also located at Alcoa. At the rolling mill, all a-c. equipment is connected to a 440

FIGURE 2—Diagram showing the double bus power system of the Alcoa plant.



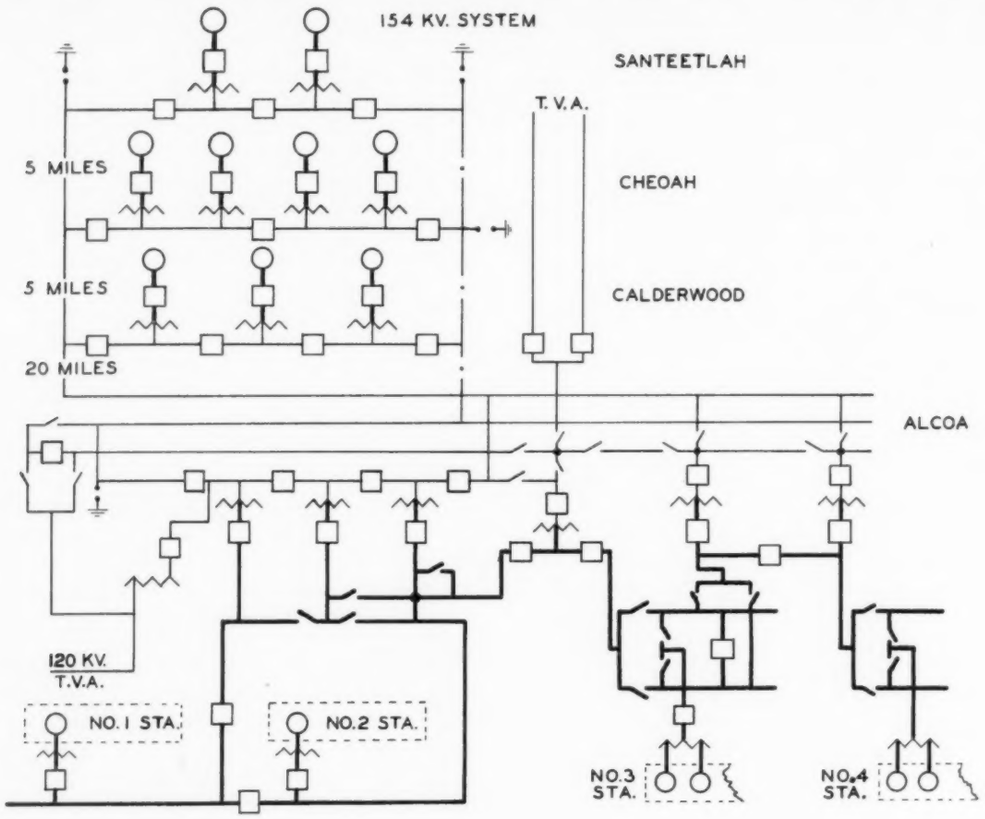


FIGURE 3—Single line diagram of the power system of the Alcoa plant.

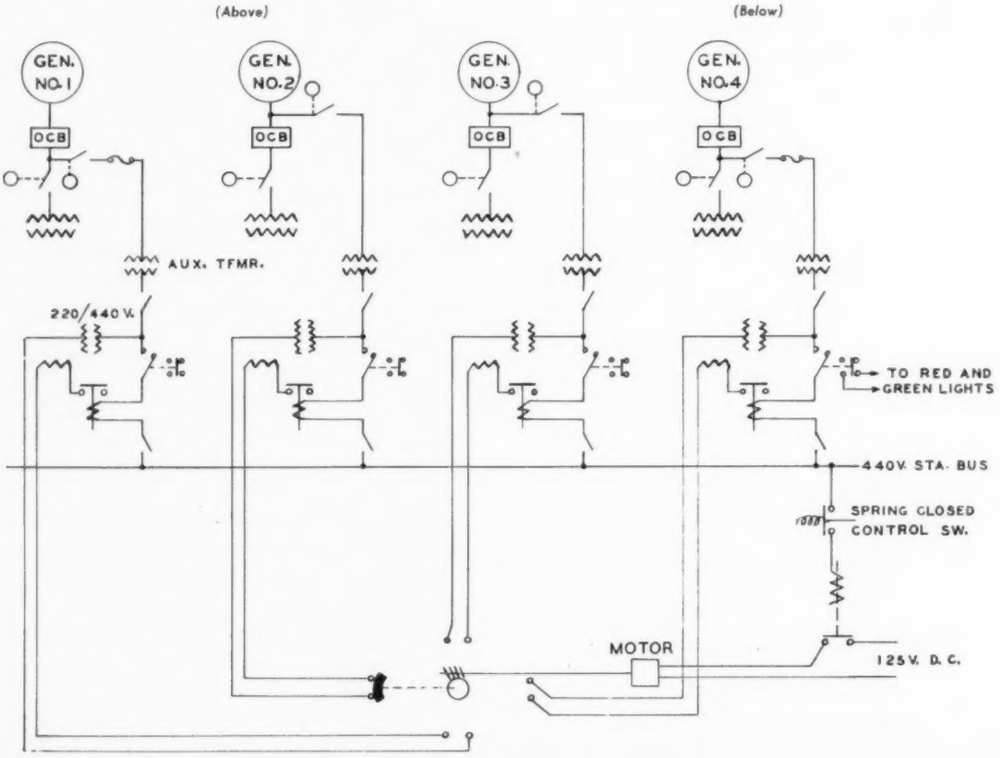


FIGURE 4—Diagram of typical station auxiliary circuits.

(Above) *(Below)*

volt network and d-c. equipment from d-c. buses fed by three large motor generator sets. The double bus idea is carried out to the 13 kv. side of the conversion and step-down transformers, and in case of equipment failure defective equipment may be cleared out in very little longer time than is required for the normal clearing of equipment before energizing the system after any interruption.

A typical station auxiliary scheme is shown in Figure 4. Individual auxiliary transformers are provided for each unit, any one of which is capable of handling the station load. No 13 kv. auxiliary switching is required with this layout, under normal conditions, the switching being done on the 440 volt side of the auxiliary transformers. The automatic selector scheme shown in the sketch is very simple and requires a minimum of interlocks. The 440 volt contactors are held closed by a-c. power from the individual circuits and no mechanical latches are required.

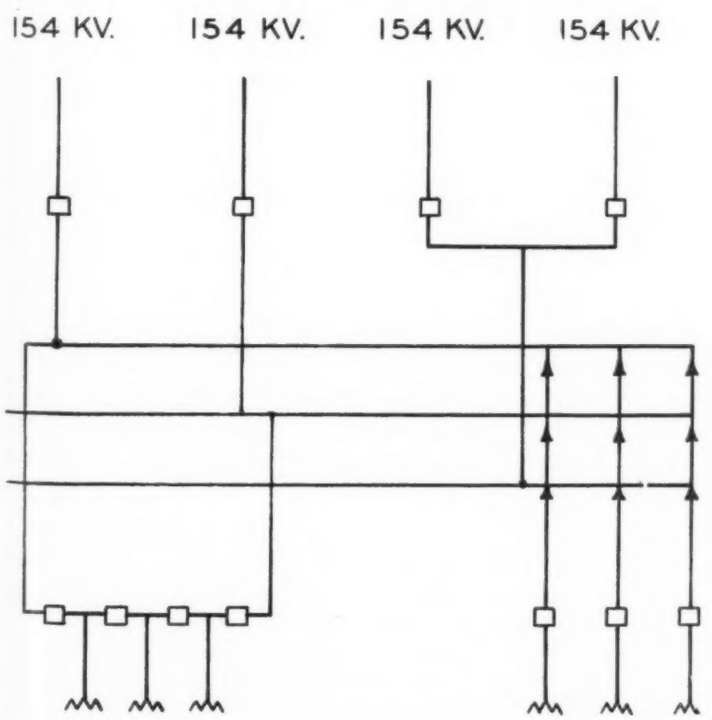
A very simple relaying scheme is used on the system. In general, for line protection, instantaneous ground relays are connected in the transformer neutrals at each station and in case of line flashover give high speed clearing of the transmission lines. Speed of clearing such disturbances materially reduces rotary converter damage from flashover. Overcurrent relays are used for back-up protection on all high and low tension breakers. Generator protection is obtained by use of generator differential relays and generator neutral ground relays. Transformer banks are protected by case ground relays, and pressure relays are now being installed on all transformers. Special bus protection relays are used at the receiving station in order to coordinate with relays on the interconnecting lines. Consideration is being given to installation of a new type of arc frequency relay now being developed.

An extensive program of oil treatment has been under way for several years on this system. Activated alumina is used for removing organic acids and other impurities from oils and suitable equipment is installed for maintaining acidity at a low value thereby preventing sludging. Activated alumina is also used as a dehydrator in transformer bushings, breathers and oil storage tank breathers.

As has been pointed out, the entire system is laid out on a double bus scheme instead of the conventional loop scheme. Each power house is tapped on the transmission lines and likewise load blocks are tapped on the double buses at the receiving station. The essential difference is that the double bus scheme is much simpler than the loop scheme and a great saving in cost is realized by the use of the double bus scheme. Certain switching combinations for removing equipment from service and certain relaying systems are possible with the loop system but it is felt that the gains from increased simplicity overweigh these advantages of the loop system. Industrial plant requirements are ordinarily quite different from the public utility system requirements and advantages have been taken of these differences for simplification of this layout. The system started with one generating plant connected to the Alcoa plant by a single line. Later a second generating plant was built, the first line extended to it and a second line built connecting the two plants to Alcoa. This second line may be used as a spare or alternate feed, or the two lines may be operated in parallel to reduce losses. New plants are added by simply tapping the two buses. The buses, at a slight increase in cost, were made large enough to carry the heavier loads with a single bus in operation without excessively high losses. Any piece of equipment may be removed from service without interfering with power supply to the plant. Any additional lines built will be in pairs and will readily fit into the double bus scheme. These pairs of lines will be connected to transverse buses at the receiving station allowing load blocks to be tied to the various buses with load groups operating either paralleled on the low tension bus or split. Switching from one bus to another is done normally with oil circuit breakers but in case of equipment failure isolating disconnecting switches must be operated. The opening speed of switches is essentially the same as with the loop system. Figure 5 shows the flexibility of switching, which may be attained with the comparatively simple layout at the Alcoa receiving station.

The simple rugged parts which make up the double bus system reduce the possibility of equipment failure and allow resumption of service in ample time for industrial plant loads. There have been no plant shutdowns for transmission system failure at Alcoa except for failure of some early wooden strain insulators used on the mile-long span when the first line was built.

FIGURE 5—Simplified diagram of the Alcoa receiving station bus, showing flexibility of switching.



DISCUSSION

PRESENTED BY

C. A. POWEL, *Manager of Industry Engineering,* Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

D. I. BOHN, *Electrical Engineer,* Aluminum Company of America, Pittsburgh, Pennsylvania.

W. A. PERRY, *Superintendent of Electrical and Power Departments,* Inland Steel Company, Indiana Harbor, Indiana.

J. E. HOUSLEY, *Superintendent of Power,* Aluminum Company of America, Alcoa, Tennessee.

H. A. RANDALL, *Systems Planning and Development Department,* Duquesne Light Company, Pittsburgh, Pennsylvania.

C. A. POWEL: This paper describes an interesting power transmission scheme little used by the central station industry, but of unquestionable merit where circumstances permit its use.

In order to more clearly bring out the comparative features, I am taking the liberty of showing three fundamental plans for power transmission where there are several generating stations in a line feeding a single receiving station. (*See opposite page*).

Figure 1 shows a fully sectionalized layout. This scheme gives the ultimate in flexibility and reliability, and as might be expected, in cost as well. Assuming, as in the case of the Alcoa lines, that one circuit is able to handle the full output of all plants, then any section of transmission circuit may be taken out of service for maintenance without loss of generating capacity. Furthermore, except within the transmission section where this circuit is temporarily out, a fault on any other section of circuit may also be cleared without loss of load. The scheme is very flexible in that generating units may be put in or taken out of service at will with a minimum amount of switching. The relaying is simple, as fast balanced line relays may be used with slower single line relays for back-up. It is expensive, as is apparent from the number of high voltage breakers shown. Single high tension buses are shown for the sake of simplicity, and if double buses are used at each sectionalizing point, even more breakers will be required.

Figure 2 shows the looped-in method of connection. Fewer breakers are required than for the fully sectionalized scheme, and as in Figure 1, any one line section may be removed from service without reducing power output. If, however, a second line trips out, part or all of the generating capacity will be lost, depending upon the particular lines out of service. Relaying is somewhat more difficult than with scheme 1, but not unduly so. Low tension flexibility is retained in this scheme.

Figure 3 is the scheme described by the authors. In effect, it consists of two buses extending the whole distance between stations. High voltage switchgear is at a minimum with this scheme, resulting in a considerable saving in cost, but there are some undesirable operating features. If one line is out of service due to maintenance and a fault occurs on the other, the whole generating system is lost. Or if a double circuit flashover occurs anywhere on the line, there is also a complete shutdown, whereas in the other schemes, some capacity is still available unless the fault is in the last line section. Relaying is considerably complicated by the fact that ties between buses tend to equalize the currents in such a manner that several distinct relaying steps are required to clear the fault. It is feasible to operate the two buses normally split except at the receiving end. In this case, relaying can be done promptly, but half of the generating capacity is lost until the machines can be resynchronized.

A variation in the general scheme of Figure 3 can be made by eliminating the high voltage tie between bus sections and tying through the low voltage sides of transformers connected to the buses. This scheme has some advantage in relaying, as the impedance of the transformers will be high compared to that of the bus, and simultaneous relaying is thereby facilitated.

As the authors point out, the circumstances surrounding supply to industrial establishments differ from those of central stations and, consequently, it can be expected that the layouts used will be different. Moreover, some of the saving in switchgear can be put into the transmission lines to render them more immune to trouble. From the operating experience cited, it appears that this has been done and the Aluminum Company is to be congratulated on the excellent results obtained.

D. I. BOHN: I want to thank Mr. Powel for his very excellent discussion showing three different schemes of system connections for comparison. He has very ably presented the relative advantages of these schemes.

The utility problem is different than yours or ours. When I say "yours" I am referring to the steel industry, as a utility is forced to go to almost any length to prevent interruptions. We cannot stand long or frequent interruptions but do not feel that we can go to extreme lengths in switching cost or complexity to appreciably reduce them.

Switchgear is improving year after year with both new and better designs available, which is a help to any of these schemes.

W. A. PERRY: I would like to hear from Mr. Housley on some of the things they have done for lightning protection, because in a part of the country where you expect 80 inches of rainfall in a year there is generally a little lightning connected with it.

J. E. HOUSLEY: Our lightning season runs from the latter part of March to the first of October. Interruptions due to lightning are from eight to sixten per year.

Instantaneous ground relays connected to current transformers in the solidly grounded transformer neutrals are used for clearing the high tension lines on occurrence of a stroke of lightning. In addition back up overcurrent relays are used on each breaker. High speed bus protection relays are used on the Alcoa high tension bus.

The system will eventually be broken up into three sections with loose coupled ties on the 13 kv. bus at Alcoa between the sections. During severe lightning disturbances which may give continuous danger of interruption for periods as long as four hours, the ties will be opened and the three sections operated independently. The danger of storm involving all three sections at one time is rather remote.

I appreciate Mr. Powel's comments on the various types of systems. Our system is a type which is adapted to our particular problem. Your own problem will require studies both as to economics and operating methods to determine the type best suited to your particular industry.

H. A. RANDALL: What is the distance between circuits? Are they on the same right of way or separate right of way?

J. E. HOUSLEY: They are on the same right-of-way. The single circuit lines are spaced 70 feet center to center but both run along the same right-of-way. However, the two 154 kv. lines from Tennessee Valley Authority are in an entirely different section.

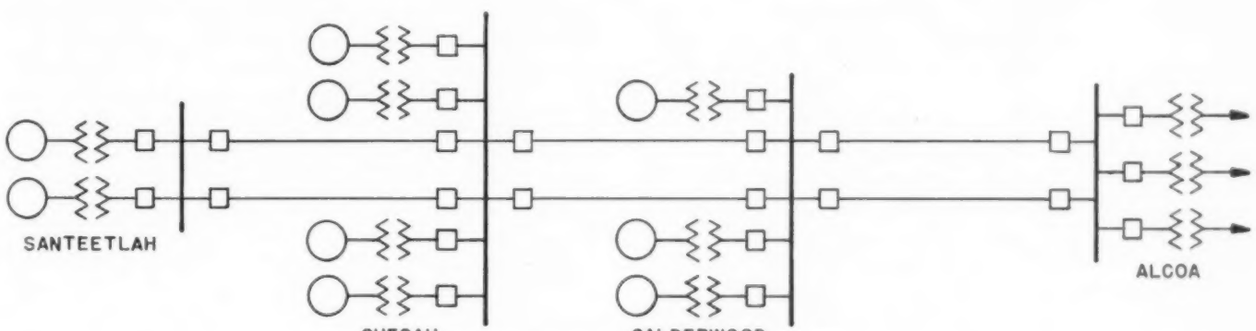


FIG. 1 FULLY SECTIONALIZED SCHEME

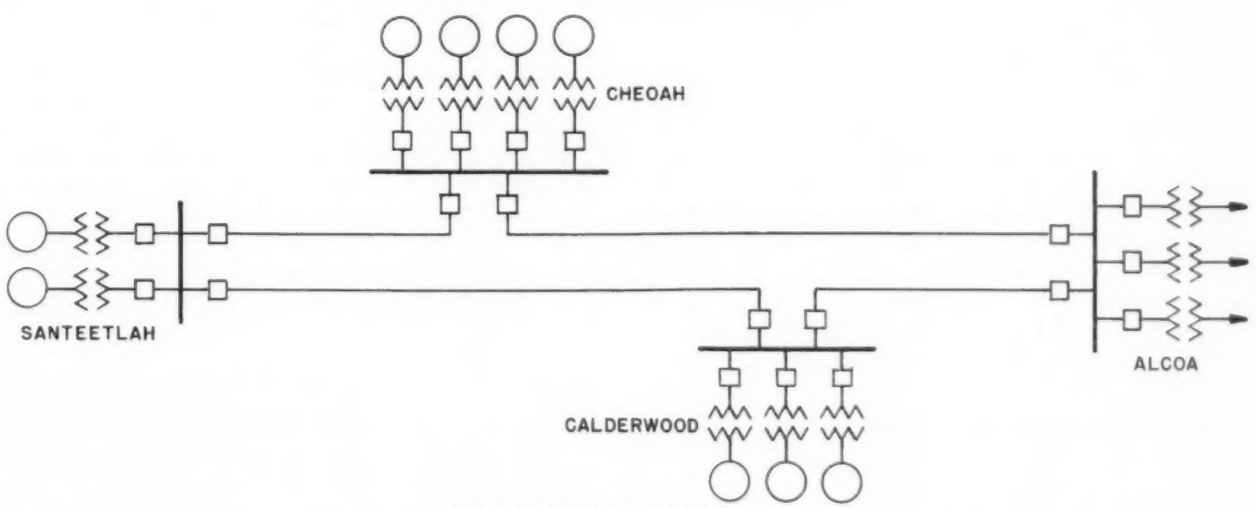


FIG. 2 LOOPED-IN SCHEME

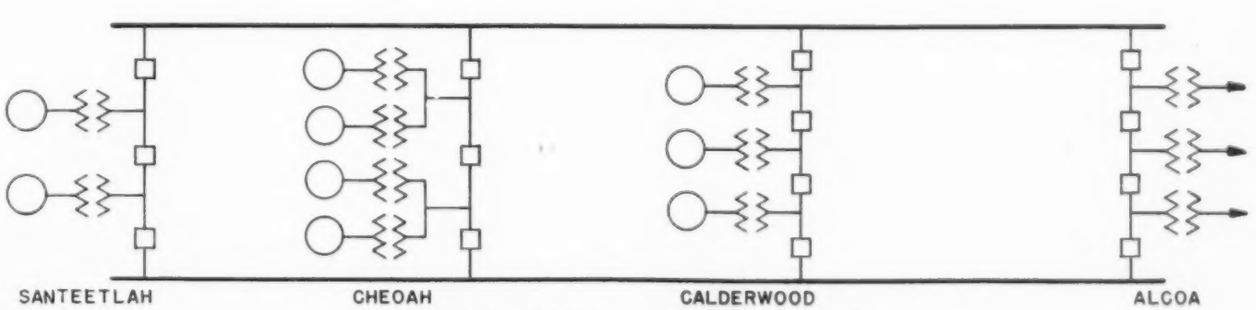


FIG. 3 EXTENDED BUS SCHEME—H. T. TIE

WELDING ELECTRODES

and Their Applications

By J. H. DEPPELER, *Chief Engineer*

METAL *and* THERMIT CORPORATION

NEW YORK, N. Y.

Presented before A. I. S. E.
Annual Convention
Pittsburgh, Pennsylvania, Sept. 26-29, 1939

▲ IN metallic arc welding, an arc is "struck" between the end of a short length of wire (usually 14 in. or 18 in. long) held in an insulated holder flexibly connected to one terminal of a welding generator and the material to be welded, connected to the other terminal of the generator. The wire is consumed and forms the weld metal.

Coatings on the electrode wire melt (or burn) with the wire and thus form a vaporous (or gaseous) shield around the metal and metallic vapor being transferred across the arc and thus protect it more or less from the oxygen and nitrogen of the atmosphere. For rather complete protection the coverings on the wire must be heavy rather than light flux coatings or even lighter dust coatings. All of the desirable elements in the core wire of the ordinary carbon steel electrode—*i. e.*, iron, carbon, manganese, silicon—are readily oxidized at the high temperature of the arc if oxygen be present and not only would the weld metal be impoverished of these strengthening elements but some of their oxides might become entrapped in the deposited metal and form detrimental gaseous and slaggy inclusions. The nitrogen of the air also readily combines with these elements in the arc and the resulting nitrides have perhaps even more harmful effects on the physical properties of the deposited metal.

The electrode coverings are of two general types: cellulosic or mineral, or combinations of these two. The earlier cellulosic types used paper, sawdust, cotton, wood-flour, or, perhaps, such carbo-hydrates as wheat-flour and rice-flour. More recently with the increase in the manufacture of rayon, the alpha and beta-cellulose materials have become available. The mineral coverings usually consist of metallic oxides and silicates. Many electrode coverings use these alone without any cellulosic or combustible ingredients and others are designed with mixtures of oxides and silicates combined with 5 to 30 per cent cellulosic material. The mineral

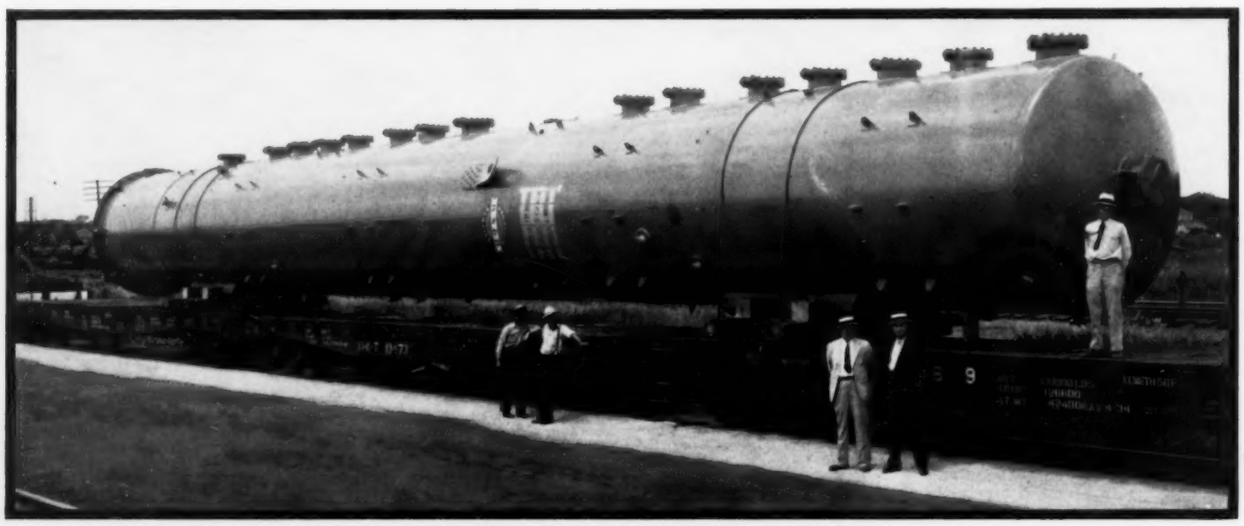


FIGURE 1—View of bubble tower, 9 ft. 6 in. x 96 ft. 4 in., $\frac{3}{4}$ in. heads, $\frac{5}{8}$ in. shell. The entire structure was stress-relieved and all welds X-rayed.

ingredients of the covering form vapors surrounding the molten and vaporized materials from the core wire as they pass through the arc, protect them from the gases of the atmosphere and deposit themselves as a molten slag covering on the weld metal, in turn protecting it. Cellulosic and other combustible materials in the covering burn in the oxygen of the atmosphere or in oxygen supplied by the covering and thus shield the metals and vapors in the arc.

In addition to the gaseous and vaporous shielding, the covering is designed to form an inverted crucible on the end of the electrode, thus shortening the exposed part of the arc and still further shielding it.

In general, the electrodes for welding iron and steel consist of mild steel core wires covered with a carefully designed mixture of mineral oxides and silicates with or without a percentage of combustible material all carefully selected as to analysis and particle size so as to:

1. Vaporize or burn and thus shield the materials being transferred across the arc from the oxygen and nitrogen of the atmosphere. The importance of this is that it not only avoids the introduction of oxides and nitrides into the weld metal but also conserves the elements which have so important an effect on the physical properties of the weld metal.

2. Offer sufficient resistance to fusion to create and maintain on the end of the electrode a symmetrical and inverted crucible neither too deep nor too shallow. The mineral or inorganic ingredients of the covering are essential to protect the organic or combustible materials from premature decomposition.

3. To continuously furnish to the arc materials to control its resistance and, therefore, the arc voltage, and others to stabilize the arc, cause it to operate smoothly, without wandering or spatter.

4. To furnish those mineral oxides and silicates which will produce on vaporization and subsequent solidification a complete dark spongy slag blanket, so light and porous that it cannot depress or deform the weld metal but with a smooth top surface completely excluding the gases of the atmosphere: a slag which, on cooling, wil shrink away from the weld metal and because of its fragility be easily cracked and brushed away. This slag blanket on the weld metal also serves to retard slightly the solidification of the weld metal and thus to allow gases to escape.

All of these things are accomplished in various ways by electrode manufacturers:

1. By dipping the core wires into thin flux pastes as many times as necessary to produce coatings of suitable thickness.

2. By extrusion of blended mixtures of dough-like consistency on to the plain core wire.

3. By applying an open spiral winding of asbestos or cotton and by extruding a thick flux paste completely filling and covering this spiral.

4. By impregnating a woven fabric with flux materials and wrapping it around the core wire.

5. By covering a core wire with flux and wrapping with plain or asbestos paper.

6. By applying a woven wire mesh to the core wire and extruding a flux to fill the mesh, leaving the top of the wire exposed.

One of the earliest manufacturing methods was that of dipping. The thin liquid pastes necessary in this process naturally produce concentric coatings but in applying six or more superimposed concentric layers, the thickness of the final coating at the lower end may be slightly greater than that at the top. Furthermore, it is difficult even with agitated dipping solutions to combine in these thin pastes materials of different specific gravities. For certain electrodes the higher percentages of liquid silicates necessary to form these liquid pastes are an advantage but for others they are a distinct disadvantage.

The high pressure extrusion process enables the manufacturer to use flux mixtures that use very little liquid so that the electrode designer can produce results that

FIGURE 2—Mill pinion stand, 20 in. centers x 36 in. face, of composite fabrication using both castings and rolled steel.

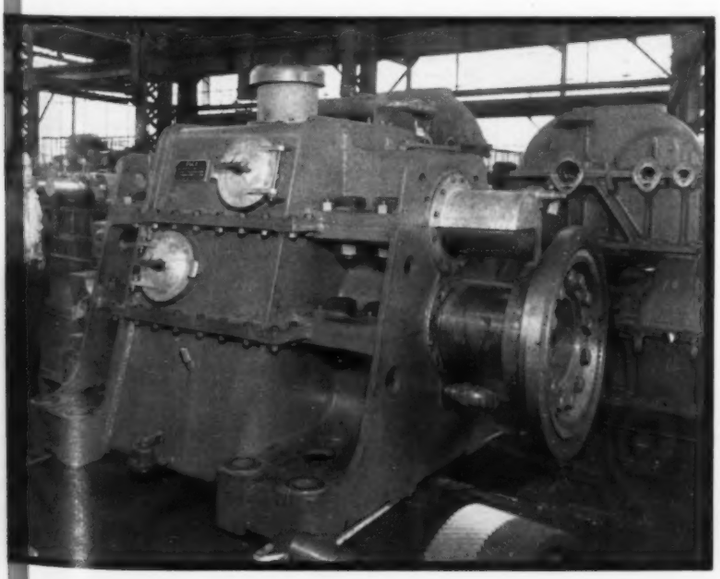


FIGURE 3—View of mill reduction gear. Carbon-molybdenum electrodes are often used for welding heavy equipment of mild steel.

would be difficult if not impossible with the more liquid dipping pastes. The difficulties that beset him are numerous, however: concentricity of coating (specifications limit him to three thousandths of an inch); crazing and cracking of coatings in drying; lack of adherence of the dry coating materials to the core wire; and fragility of coating. Modern methods of extrusion, wire guide and die assembly construction have simplified his problems but suitable perfection requires eternal manufacturing vigilance.

Asbestos or cotton yarn wound in open spirals does eliminate this concentricity problem but introduces others. For heavy current down-hand welding, the concentricity and ruggedness of this type of construction have advantages but for electrodes to be used in vertical and overhead positions, the higher pressure, greater density coatings of the plain extruded type have advantages in that they avoid "spiraling" at the lower amperages used and the greater density of the coating shell on the wire tends to more accurately direct his lower amperage arc. The spiral winding, on the other hand, guarantees the concentric coatings which are so essential to uniform high amperage performance. The soft asbestos winding acts as a packing in both the entrance and exit dies of the extruder, prevents the high pressure flux from escaping and holds the core wire rigidly concentric.

Impregnated tapes wrapped around the core wire simplify manufacturing and produce electrodes quite suitable for welding in positions other than flat. Thick tapes are used for electrodes for flat position work. In one case, this impregnated tape idea has produced one solution of the problem of introduction of welding current into electrodes used in automatic welding heads: the coating in tape form is wrapped around the core wire between the automatic head and the arc. Automatic welding in another case is accomplished with this tape type coating by slitting the coating as it passes through the head to enable the current to be introduced to the core wire through this slit.

That type of electrode in which wire mesh is woven or wrapped around core wire and flux extruded in this mesh makes it possible to introduce current into the core wire through the exposed surface of the mesh.

The most suitable core material for iron electrodes is a high grade rimmed steel; killed or semi-killed steels do not seem to function as well. Specifications usually call for:

Carbon	.13 per cent to .18 per cent
Manganese	.40 per cent to .60 per cent
Silicon	.06 per cent
Sulphur	.04 per cent max.
Phosphorus	.04 per cent max.

The carbon and manganese contents affect the tensile strength of the weld metal and to some extent the smoothness and soundness but the sulphur content is all important and where perfect weld soundness is required, it should be as much below .04 per cent as is reasonably possible. The phosphorus content is much less important and were it not for limitations of this element in specifications, even .07 per cent phosphorus in core wires would not be harmful.

There are still unknowns in the selection of perfect core wire but recently one of the mysterious variables was found to be in the surface finish of the core wire, the very slight film of oil on this surface, or its absence, the slight remnants of a drawing compound. The modern bright clean finish has been a definite advance. But there still are other mysteries which may soon be solved by the steel-maker by changes in his practice, his control of gas content, or the rate of reduction in his wire

FIGURE 4—Test specimens taken from pipe to pipe weld made with covered carbon-molybdenum electrodes.

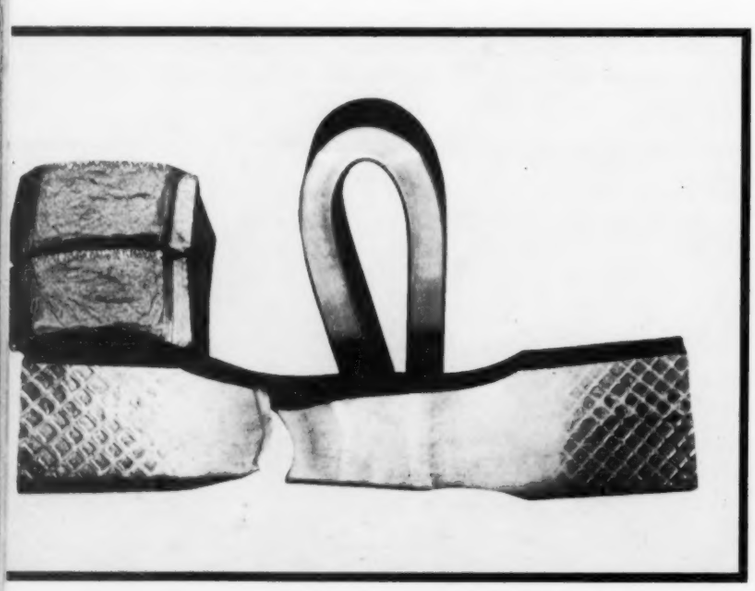


FIGURE 5—Nickel steel plate, welded with covered nickel steel electrodes, was used in this refinery wax filter.

drawing. Until then, variations from heat to heat of practically the same chemical analysis will still be found by the electrode manufacturer and by the user in minute porosity or in spatter or those operating recoils on the electrode holder noticeable only to the highly skilled operator but which will continue to cause minor differences in weld quality.

At the end of the electrode in operation, there is a miniature electric furnace; the core wire is the metallic charge and the coating forms the essential slag through which the metal is refined, the content of harmful ingredients reduced and that of the beneficial elements —carbon, manganese and silicon—controlled. The coating design is not a hit and miss proposition and the amount of each compound present must be just enough to combine with some other. An electrode designer must be not only a chemist but a metallurgist. He has numberless elements and compounds to work with and even variations as small as one per cent will have a noticeable effect on the performance of the resulting electrode.

A list of only some of the most used materials is given below:

Metals: manganese, silicon, zirconium, magnesium, calcium, aluminum, iron, sodium, potassium.

Metallic oxides: titanium oxide, silica, magnesia, iron oxide, alumina.

Silicates, solid and liquid fluorides: magnesium silicate, sodium silicate, asbestos, clay, feldspar, fluorspar.

Cellulose: cotton, paper, wood flour, alpha cellulose.

Binders: gums, resins, glues, lacquers.

In general, the elements higher in the electro-chemical series emit electrons in greater numbers and, the greater the chemical activity of an element, the easier it is to ionize. Both of these properties are kept constantly in mind by the electrode designer.

In carbon arc welding, the electrode was usually connected to the negative terminal of the welding generator to avoid the introduction of carbon from the electrode into the weld metal. This (electrode negative) became to be known as direct polarity. Most heavy coated electrodes are used with electrode positive, *i. e.*, reversed polarity.

Electrodes with more than about 10 per cent cellulose in the coating frequently give very unsatisfactory performance on alternating current, as it is most difficult to maintain an arc.

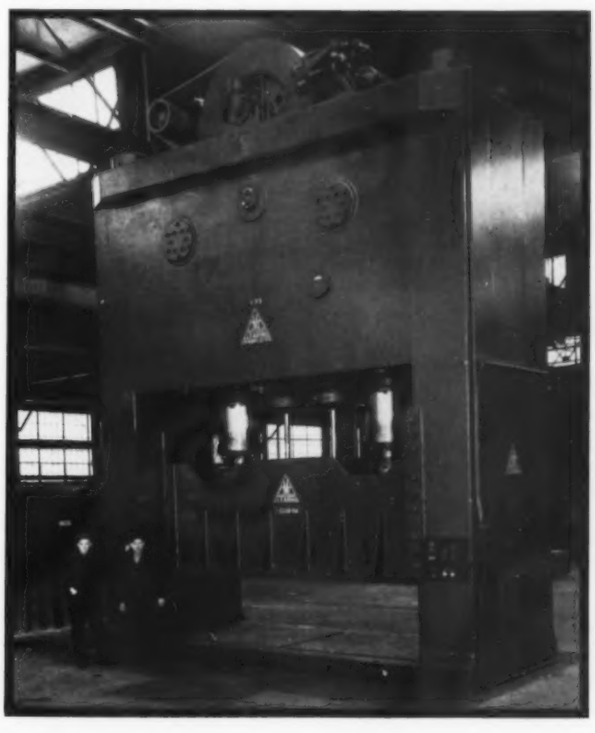
While in general the amperage used controls the rate of welding, the arc voltage affects the amount of penetration into the metal being welded. Undue penetration is usually undesirable because the penetrated portion of the parent metal mingles with the weld metal and may completely change its character.

The effect of this is most noticeable in welding the higher carbon steels, where with deep penetration the lower part of the weld may easily consist of equal parts of metal from the electrode and from the material being welded. Now the carbon content of weld metal has so pronounced an effect on the tensile strength that an increase of only a few hundredths of one per cent corresponds to an extra 10,000 lb. tensile strength. A carbon content of only .09 to .10 per cent in weld metals corresponds to about 63,000 lb. per sq. in. and .11 to .12 per cent carbon to 72,000 lb. per sq. in. Imagine, then, the effect of a 50/50 mixture of such a weld metal with, for instance, a .35 per cent carbon steel, the resulting weld metal with perhaps more than .20 per cent carbon, would have a tensile strength of well over 100,000 lb. per sq. in. and would undoubtedly be so brittle that it would crack on cooling. The cure for this difficulty would be the avoidance of all penetration not necessary to bond the weld metal in with the parent metal. The electrode designer can control the arc voltage and, therefore, the penetration and if the welder uses a proper technique avoiding too great melting of the high carbon steel, the danger of cracked welds can be eliminated. To a certain extent, also, coating thickness affects the fluidity of the deposited metal, the rate of deposition (by requiring higher amperage for normal operation) and the amount of penetration. As an extreme case, bare wire electrodes can be used to weld really high carbon steels with a minimum of pick-up.

All steels with over .30 per cent carbon or with a higher tensile strength than perhaps 70,000–75,000 lb. per sq. in. should be preheated prior to welding. Preheat acts like stress relief to minimize the relative contraction of the weld metal and parent metal. Preheat does before welding what stress relief does after welding. With preheat, slightly thicker layers of weld metal can be used without fear of coarse-grained laminations and "fish-eyes."

Highly ductile weld metals usually call for "heavy" coverings on electrodes and with care these can be used even with parent metals containing elements and sonims that would be undesirable in the weld metals: penetration and pick-up can be minimized by aiming the

FIGURE 6—Fabricated construction was used in this 2200 ton press for forming freight car ends.



electrode directly down at the already deposited metal and weaving carefully from side to side so that the arc does not touch the edges of the parent metal but radiates its heat against the sides of the groove until they "sweat." Then as the arc is moved away, the deposited metal will flow against these side walls and join them in a smooth meniscus.

In general, the thinner high density coatings and those with the higher contents of cellulose produce weld metals with a little less fluidity. They are more suitable for vertical and overhead welding and produce fillets that are slightly convex. In general, also, the heavier coatings and coverings produce more fluid weld metals and their principal use, therefore, is in down-hand welding or in horizontal fillets with surfaces that are concave. Usually the more fluid deposits produce thinner and more numerous multi-layers and greater grain refinement.

Faulty technique and unclean parent metals are frequently responsible for these defects and these matters are discussed elsewhere but the electrode may just as frequently be responsible. Gas holes in the weld may be due to "gassy" metal in the core wire of the electrode, to too high a sulphur content in the core wire or the coating, or to insufficient arc protection allowing metallic oxides to go into solution in the highly superheated and fluid deposited metal. Improper arc protection, in turn, may be the result of poor coating design or of undue eccentricity of the coating reducing the protection on the thin side.

Slag inclusions are usually due to faulty technique, but again the coating design may be responsible. Inequalities, miniature explosions, arc blow, swirls, etc., all may violently agitate the freshly deposited metal and slag, and cause entrapment.

Elements like molybdenum, nickel, vanadium, copper, chromium and tungsten are frequently used in electrode design, and may be added either through the use of alloy core wires or added through the coating. By means of their use, weld metal tensile strengths as high as 100,000 lb. per sq. in. combined with elongations of over 20 per cent in 2 in., or as low as 63,000 lb. per sq. in. with ductilities over 40 per cent in 2 in., can be obtained. Other combinations affect hardness, corrosion resistance, cavitation resistance, creep strength, low temperature impact values and resistance to fatigue.

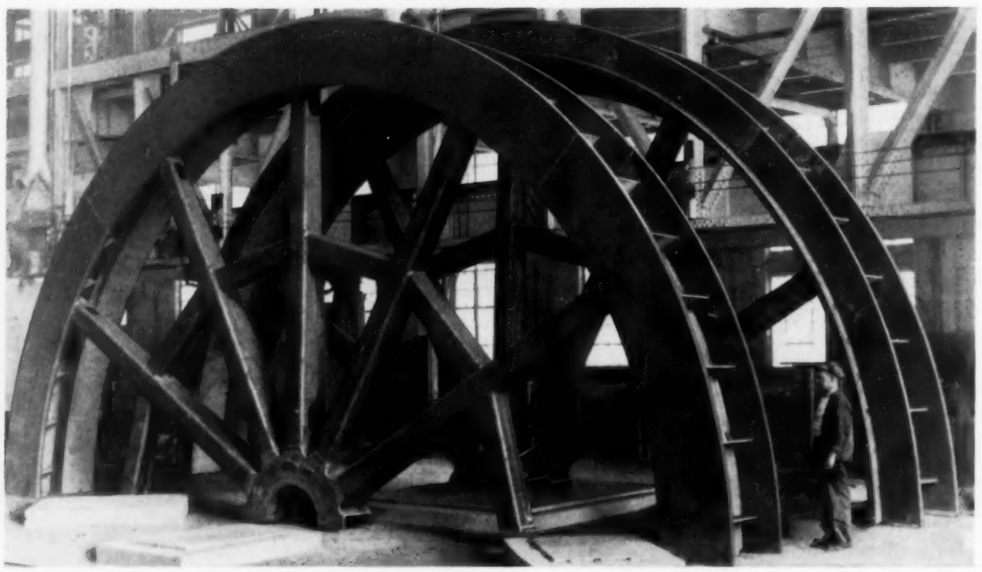


FIGURE 7—This fabricated pot chuck for a special machine tool application is the largest ever built.

In designing an electrode for use in welding alloy steels, it is, of course, more important to match the physical properties of the parent metal than it is to match the chemistry. Usually both cannot be done. Just as the carbon content of electrically deposited weld metals must be considerably less than that of the parent metal for a given tensile strength, so must the carbide-forming elements be lower. Weld metals because of their very rapid quench and their grain refinement are harder, more corrosion resistant, and stronger than rolled steels of the same analysis. Chromium, as an example, forms carbides readily so that if, to match the chemistry of a 5 per cent chromium steel, the electrode designer should provide a tool to make a 5 per cent chromium weld metal, the weld would be 50 per cent stronger than the parent metal and so hard as to be almost unmachineable. Three per cent chromium would suffice. There are, of course, inhibiters, such as titanium

and columbium, which would, to a great extent, prevent the chromium carbide from forming and where they are used in sufficient quantity, the chromium content of the weld metal may be allowed to almost equal that of the parent metal. The elements nickel and molybdenum seem to have quite a beneficial effect in electrodes not only on the smoothness of operation and on the soundness of the resulting weld metal but also in "stabilizing" the more readily oxidizable elements and cause them to vary less with changes in arc length, arc voltage and other manipulative differences.

Adding alloying elements by means of special analysis core wires in some cases adds something to the ease of manipulation and welding properties but is more expensive than the use of ordinary steel core wires with coatings containing these alloying elements. Alloys from the coating, on the other hand, seem to be more uniformly efficient as they pass through the arc, and are less affected by variations in arc length.

The amount of alloying element that can be added through the coating is, of course, limited, but amounts up to about 15 per cent can be added where the electrode use warrants. As an instance, it is perfectly feasible to use plain carbon steel core wire and by means of a properly designed coating to add enough manganese to produce austenitic manganese steel with its 13 per cent manganese and 1 per cent carbon. Higher percentages such as those required for the austenitic nickel chromium steels 18/8 cannot be produced by coating additions alone but require some part at least of the chromium and perhaps part of the nickel in the core wire.

So, here again, the electrode designer can take advantage of the excellent welding properties of the mild steel core wire and still produce his high alloy steels or in other cases use alloy steel core wires to control arc voltages and stabilization, efficiency of deposit and weight of coating. In some cases, one should be used and in others the more expensive alloy steel core wires; cost alone seldom decides these cases.

In the accompanying tabulation are given the chemical analyses and physical properties of weld metals from bare electrodes and from coated electrodes. Both are from approximately the same mild steel core wires. The remarkable beneficial effect of the coatings is self-evident.

TABLE I

Physical Property Comparison

	Mild steel	Bare electrode	Shielded arc electrode
Ultimate tensile strength, lb. per sq. in.	55,000–70,000	50,000–60,000	60,000–75,000
Yield point, lb. per sq. in.	30,000–42,000	38,000–45,000	45,000–60,000
Elongation in 2 in., per cent	30–40	5–10	20–40
Izod impact, ft. lb.	50–80	5–15	40–70
Endurance limit, lb. per sq. in.	26,000–30,000	12,000–18,000	26,000–32,000
Specific gravity, grams per cu. cm.	7.86	7.5–7.7	7.80–7.86
Corrosion resistance, acid	....	Poor	Better than mild steel.
X-ray	Perfect	Porosity	Perfect

Chemical Analysis Comparison

	Electrode core wire	Bare electrode deposit	Shielded arc electrode deposit
Carbon	.13–.18	.03–.07	.08–.15
Manganese	.40–.60	.05–.30	.35–.60
Sulphur	.040 max.	.035 max.	.035 max.
Phosphorus	.040 max.	.035 max.	.035 max.
Silicon	.060 max.	.060 max.	.30 max.
Oxygen	.060 max.	.20–.35	.04–.08
Nitrogen	.008 max.	.10–.15	.010–.030

In addition to its remarkable effect on the physical properties of the weld metal, the coated electrode is a great boon to both the weldery and to the welder. The phenomenal increase in the number of machines and structures fabricated by welding and the greater dependability of these fabrications, the new fields opened up by the lightness and unique designs made possible by

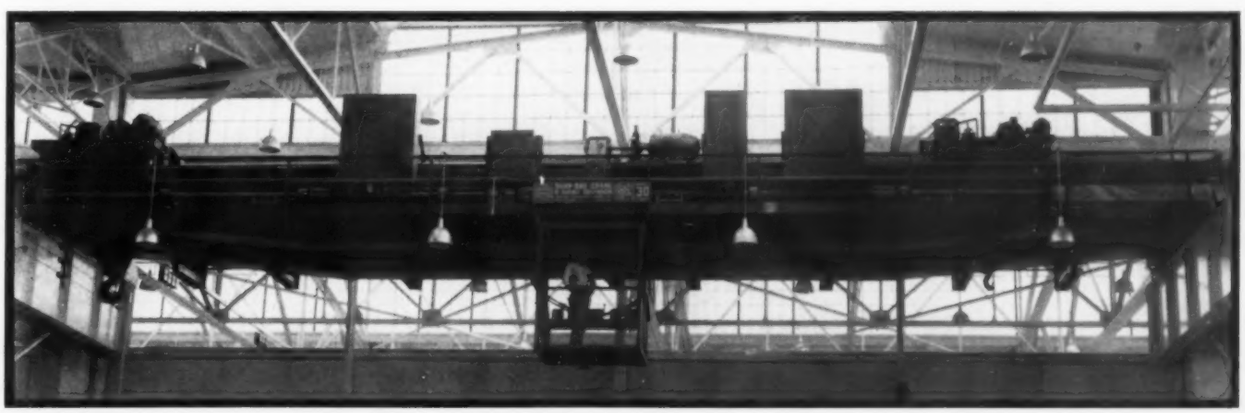
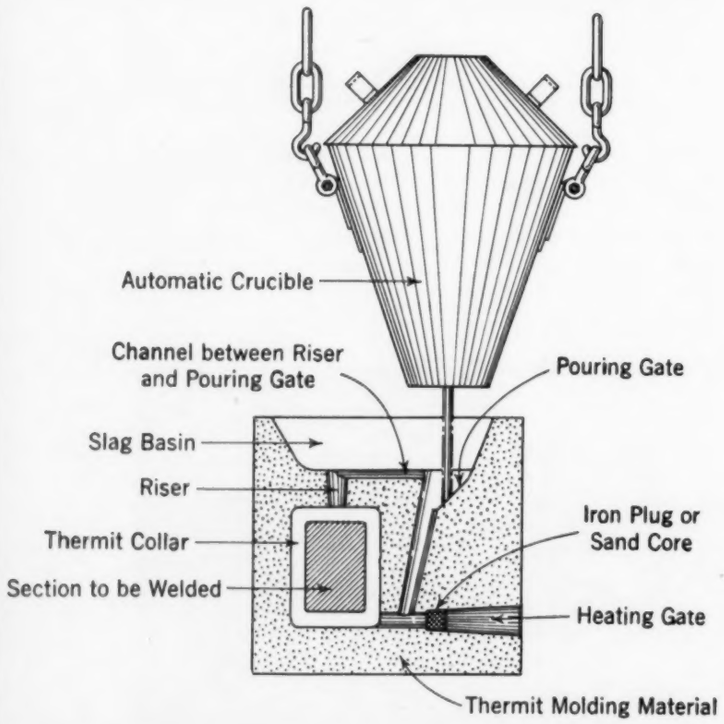


FIGURE 8—View of an all-welded crane of thirty tons capacity.

this welding— these subjects are all discussed elsewhere. But the welder himself has become a master craftsman, and the electrode coating has helped him. The arc itself is partially hidden from his view—the weld becomes more visible. The arc length is more easily controlled and if for a brief instant the tip of the electrode actually touches the work, it does not stick as bare wire did and extinguish the arc, but the welding proceeds smoothly. The coating is a dielectric and the sides of the electrode can touch the sides of the work without short-circuiting. He can work in confined spaces, bend the electrode to reach otherwise inaccessible places.

But the greatest help of all is the fluid puddle of molten slag which an experienced welder watches all through the welding operation. It is a perfect indicator of how fast to advance and how fast to weave from side to side. Through the medium of coating design, the fluidity of the slag may be controlled, but usually it follows about $\frac{1}{8}$ to $\frac{1}{4}$ in. behind the arc. If this distance increases, the operator knows he is advancing too rapidly for that particular electrode size and that current. Conversely, if the slag crowds too close, he must proceed faster. Likewise on the weaving, as he moves to one side, the slag sluggishly moves to the other and starts to flow ahead. This again is the operator's cue and he weaves slowly back just in time to avoid the slag's getting ahead, being cut off and entrapped in the weld metal.

FIGURE 9—Diagram showing method of pouring and detail of mold for thermit welding.



In general, the lighter the coating, the more "efficient" the electrode; bare wire is over 90 per cent efficient. By efficiency, we mean, of course, the ratio of the weight of effective deposit to the weight of the original electrode. As a corollary, the rate of deposition increases with coating thickness—it is least for bare wire. Light coatings save electrodes costing perhaps 8 cents per pound, while wasting operator's time at a dollar or more per hour. Modern heavy coated electrodes in the $\frac{1}{4}$ in. size, for example, can deposit 13 lb. per hour, more or less, depending on current strengths—the corresponding $\frac{1}{4}$ in. bare wire perhaps 4 lb. per hour.

The amount of current that can be used with a given size electrode depends not only on the character of the weld being made and upon the position in which the welding is being done but also on the character of its coating. Electrodes with a high cellulosic content are usually better for vertical and overhead welding at the lower current values and the all-mineral coated for downhand welding at the higher current values. Slight cellulose additions reduce the amount of slag and require only a slight reduction in amperage.

The current values shown in the table illustrate this point; the values are approximate and wide variations will be found in actual practice, depending on whether a-c. or d-c. is used and upon the skill of the operator. Such extremes as the use of 1000 amperes with a $\frac{3}{8}$ in. electrode and 300 amperes with a $\frac{3}{16}$ in. electrode may readily be found.

Cellulosic Type

Electrode diameter, in.	Flat (amperes)	Vertical and overhead (amperes)
$\frac{3}{32}$	60	60
$\frac{1}{8}$	120	110
$\frac{5}{32}$	150	140
$\frac{3}{16}$	190	160
$\frac{1}{4}$	275	. . .
$\frac{5}{16}$	325	. . .
$\frac{3}{8}$	400	. . .

All Mineral Coated Type

Electrode diameter, in.	Flat (amperes)
$\frac{1}{8}$	150
$\frac{5}{32}$	220
$\frac{3}{16}$	350
$\frac{1}{4}$	500
$\frac{5}{16}$	625
$\frac{3}{8}$	900

Each year improvements are made that affect the ease of handling, the smoothness of the deposited metal surface, the convexity or concavity of fillet welds, the tendency to undercut and the electrode as a tool becomes more and more desirable. What the end is no one can predict but electrode sales have doubled each year or two and even now approximate the astonishing total of ten million pounds a month.

THERMIT WELDING

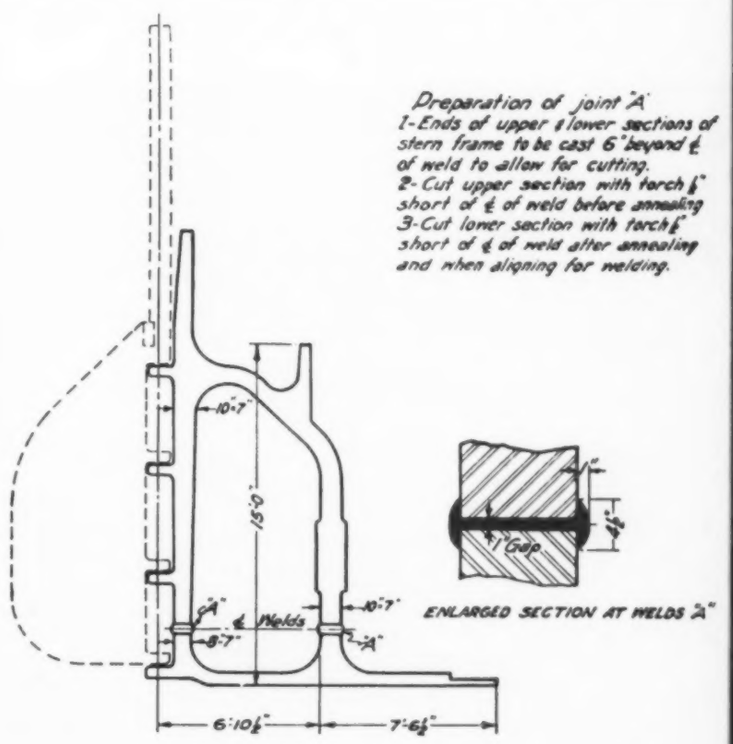
About thirty years ago, a German scientist, Professor Dr. Hans Goldschmidt, made an important discovery upon which the whole science of alumino-thermics depends. It was known for many years that aluminum had a greater affinity for oxygen than any other element and was, therefore, very useful in the reduction or deoxidation of most of the metallic ores and oxides; and other inventors, notably Moissan, Vautin, and Greene and Wahl, used this process of aluminum reduction in the actual production of the rarer metals—pure manganese, ferro-vanadium, pure chromium and the other metals resulting from the reduction of similar very refractory oxides. The method pursued by these other inventors was the simple substitution of aluminum for carbon as the reducing agent, the carbon requiring the application of considerable heat to cause it to react with the oxides, whereas the aluminum because of its greater affinity for oxygen reacted much more actively; but the methods were the ones used in the carbon reduction process, that is, the mixing of the reducing agent and oxide in empirical proportions based on the known chemical reaction and the external heating of this mixture until the reaction took place.

Dr. Goldschmidt's contribution to the art was the discovery that, if a mixture of metallic oxide and finely divided aluminum were ignited in one spot, the reaction of this spot would furnish sufficient heat for the propagation of the reaction through the mass of the mixture until the entire contents had been converted into a seething mass of the metal itself and molten aluminum oxide slag; and that this reacton wiould in most cases proceed in a cold mixture of the oxide and aluminum at a rate which would make possible the production of a ton or more of material in a single reaction lasting only thirty seconds.

We will not deal here with the reduction of ores and oxides in general, but will confine ourselves to the thermit welding process, which depends principally on the alumino-thermic reduction of iron oxide, and we will omit the reasons for the selection of Fe_3O_4 instead of any of the other oxides of iron for the welding process, the great importance of the flake form of this oxide and the control exercised on the speed of the reaction by the physical size of these flakes and the percentage of fines included in the mixture. Furthermore, we will only briefly mention that the speed of reaction in the welding process is also controlled by the addition of metallic elements to the thermit mixture and by the addition of such elements as chromium, vanadium, and manganese, any of which may be either in the form of metallic oxide and aluminum or in the form of metallic particles. The designer of thermit mixtures for use in welding has at his disposal many variables so that he is able to definitely control not only the speed and temperature of the reaction but at the same time the chemical analysis of the resulting steel, and through these to predict the physical properties of the weld material.

The temperature of the steel resulting from the thermit reaction is only a little less than double the temperature of ordinary molten steel, so that, in the use of this material for welding purposes, there is available almost 100 per cent superheat and it is upon this superheat that the ability to make welds depends. This statement will probably be a little clearer after we have considered the method of making a thermit weld (see Figure 9). In general, this welding process is simple. It requires no manual dexterity on the operator's part and, if instructions are followed, the results are good. The general procedure in the case of the repair of a break is to line up the parts; to cut a parallel-sided gap at the fracture, the width of the gap depending upon the size of the section; surround the break with a refractory mold, which provides an annular space at the fracture; preheat the parts to redness by means of kerosene and air blown into the mold through an opening near the bottom, which preheating simultaneously dries out the mold; plug the heating gate and then start the reaction by means of a small amount of ignition powder placed on top of the thermit and tap from the crucible the resulting superheated thermit steel. It is obvious that this steel, having 100 per cent superheat and held in place between and around the ends of the pieces to be welded, will give up its superheat to the parts, fuse and solidify with them. If, then, the weld material has good physical properties and is sound and close-grained, and the shrinkage of the weld has been allowed for, the results should be very dependable. Let us, therefore, discuss first the physical quality of thermit steel and briefly review the important things in the thermit welding operation upon which so

FIGURE 10—Diagram showing details of thermit welded stern frame for coast guard cutter *Northland*.


Preparation of joint 'A'
1-Ends of upper & lower sections of stern frame to be cast 6" beyond ℄ of weld to allow for cutting.
2-Cut upper section with torch 1/2" short of ℄ of weld before annealing
3-Cut lower section with torch 1/2" short of ℄ of weld after annealing and when aligning for welding.
10'-7"
15'-0"
6"
℄ Welds
8'-7"
10'-7"
'A'
6'-10 1/2"
7'-6 1/2"
1" Gap
ENLARGED SECTION AT WELDS 'A'

much depends if sound welds are expected, and then proceed to the application of the process in the steel mill.

In considering the physical quality of thermit steel, the first question which naturally comes up is, how can such a cast steel possibly compare in strength with forged steel and will not the strength of the welded part be only that of a similar cast steel part and not that of the original forging? This question is of the utmost importance because, if the thermit weld be considered as having only the strength of cast steel, its application in steel mills would be very limited; but this is not the case. Forgings that have been thermit welded and tested to destruction will just as often fail completely outside of the welded area as they will in the weld or in the metal adjacent to the weld. Let us first theorize as to why this is so and then give various proofs of it. Steel, as cast, differs from forged or worked steel not in its chemical composition but only physically, and this physical difference lies to a great extent in the rendering ineffective of the weakness at the grain boundary. Commercial cast steel on solidifying throws out to the grain boundaries many impurities, and these, forming part of the cementing medium between the grains, are weaker than the grains themselves so that fractures of cast steel are usually intergranular. Now, the forging, rolling, or working of these grains distorts them, so that this grain boundary weakness is no longer of any importance and the strength of the piece is then that of the material itself and not of the weaker grain boundary. Now, instead of being a refinement of relatively impure materials thermit steels are the result of the reduction of a very pure iron oxide by an almost perfectly pure aluminum with the result that thermit steels, although cast, invariably fracture through the grains and not, as in the case of most cast steel, along grain boundaries and have, therefore, physically all of the properties of forged steel except its appearance under the microscope. This probably is the explanation; but the fact remains that in every test and by actual service thermit steels compare very favorably with the physical properties of high grade forgings.

This question came into considerable prominence during the war when a large company, thoroughly familiar with the thermit welding process, asked the approval of Lloyds' Register of Shipping of the use of this process for the manufacture of stern frames for ships. This approval was given in the case of cast steel frames but withheld in the case of forged steel frames, and the refusal was based on the consideration that, if a customer was willing to pay the extra cost of a forged steel frame, it would not be right to furnish him a forged steel frame with cast steel welds, because this would be no stronger than a cheaper cast steel frame of similar design. This contention naturally resulted in the starting of a series of tests because from long years of experience in the welding of forgings and particularly the welding of hundreds of heavy crankshafts without a single failure there was reason to believe that thermit steel could not be judged directly from the foundryman's experience. The test was very elaborate and consisted in the making of a large number of welds on 10 in. x 10 in. sections of forged steel approved by Lloyds, some of the welds being between sections with free ends and others between sections not free to move. The results of this test are available in detail to anyone who may desire them, but we give here only the impact test which, considered with the very excellent tensile test

FIGURE 11—Thermit welds are useful in both construction and repair of stern frames for ships.

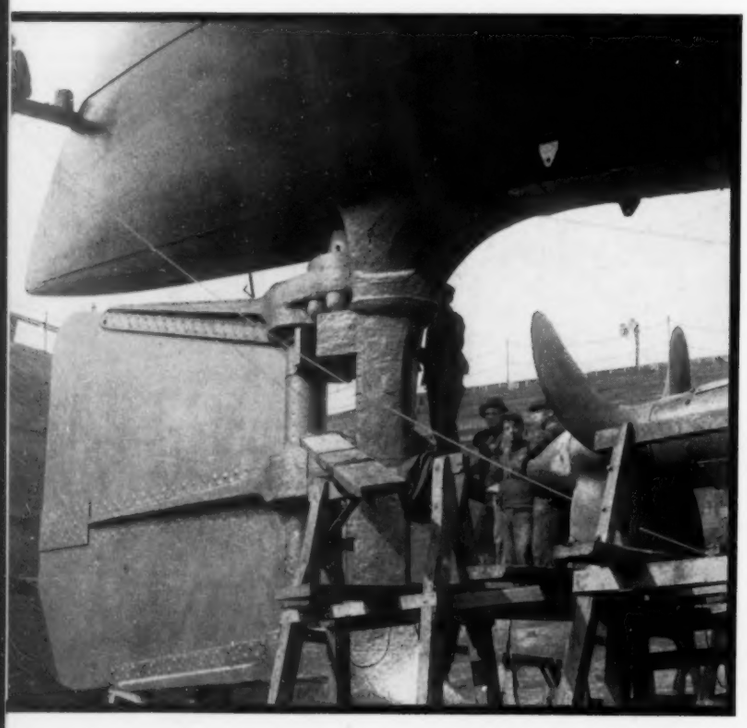


Table II—Results of Drop Test on 10x10 in. Sections of Forged Steel

Drop No.	Height, ft.	Deflection, in.
1	9	0
2	12	3/16
3	15	5/16
4	18	15/32
5	18	19/32
6	18	25/32
7	18	31/32
8	18	1 3/32
9	18	1 7/32
Billet turned over 180 degrees		
10	18	5/16
11	18	1/2
12	18	11/16
13	18	15/16
14	18	1 1/16
15	18	1 1/8

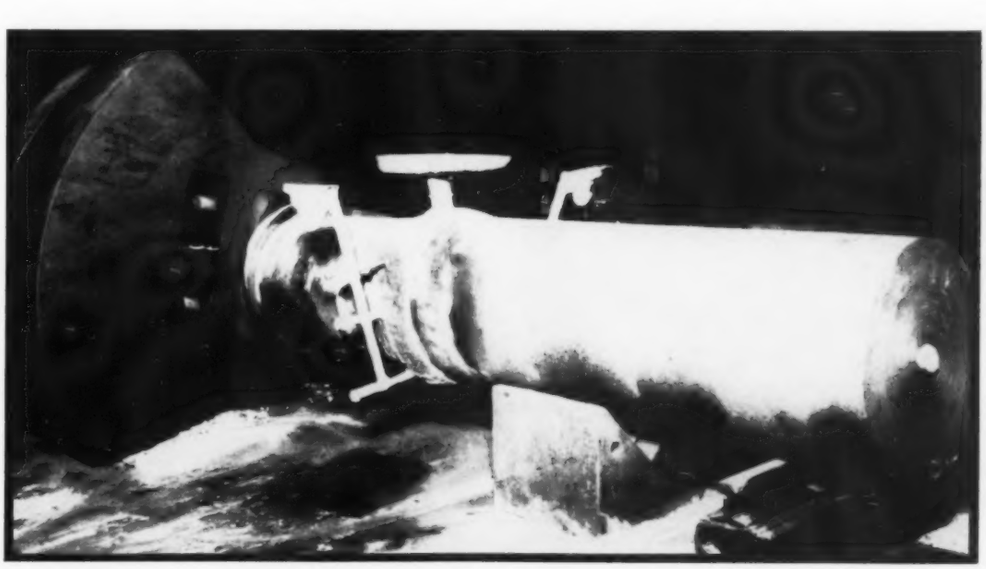
and ductility showings, resulted in Lloyds' approval of the thermit welding of forged steel frames. In the preparation of this impact test specimen, two 10 in. square pieces of Lloyds' steel, each about 3 ft. long, were thermit welded together end to end and, after welding, the piece was not annealed nor was any work done on it except the machining off of all excess metal at the weld. This resulted in a specimen six ft. three in. long with a weld at its mid-point. This piece was symmetrically supported horizontally on 5 ft. centers and a 3290 lb. pear-shaped weight dropped directly on the weld from a height of 18 ft. Progressively in nine drops, the middle of the test piece was deflected downwards $1\frac{7}{32}$ in. without any signs of distress. The piece was then turned over 180 degrees with the idea that it could then be rather easily broken if bent back again, and the drop testing continued until after six more drops the piece had been practically straightened out out again (see Table II). After this, Lloyds' engineer suggested that the weld be sectioned and examined internally rather than to continue the impact testing, which might be prolonged.

A test of a practical nature was run a few years prior to this by the Navy Department; this consisted in the welding of the crankshaft of the Submarine E-2 and the testing of this shaft to destruction at the Brooklyn Navy Yard. This piece was a two-throw shaft with hollow journals and with a flange on one end, and the break was in the main journal next to the flange. The material was a high-grade molybdenum steel. After welding, all excess metal was machined from both the inside and the outside of the shaft and the piece supported on special brackets bolted to the Navy Yard's 40-ton planer bed with a lever bolted to the flange of the shaft having a weight pan on one end and a hydraulic jack under the other. The shaft was prevented from turning by blocking under the second pin so that the test was made of the welded main journal and the unwelded main journal. The strength of the unwelded main journal had previously been practically proven when the shaft was originally broken. In the first part of the test, the shaft was gradually twisted and failed in an axial crack in the unwelded main journal. Then, the orders being to test the weld to destruction, the first pin journal was blocked to the planer bed so that all of the torsion was applied to the welded journal, but, when the heavy cast steel bearing brackets broke one by one and the $1\frac{1}{4}$ in. bolts holding the brackets to the planer bed began to stretch, the test was stopped without breaking the welded journal rather than run the risk of seriously damaging the planer bed.

Since the approval by Lloyds' Register of Shipping and by the American Bureau of Shipping, hundreds of stern frames of steamers have been thermit welded and, although in one or two cases these frames have again broken, the breaks have never been closer than 3 ft. from the weld. This, of course, is not a true test of the comparative strength of thermit steel and forged steels, because in the case of these ship welds the excess metal at the weld is usually not machined off; but it is indicative of the fact that the metal next to the weld is not harmed to any appreciable extent by re-crystallization or otherwise.

Many other tests could be described, both of the laboratory and of the practical variety, all of which would go to prove that thermit steels were the equal of most forged steels as far as fatigue and impact values are concerned. The other physical qualities are easily controlled between certain wide limits by the designer of thermit mixtures. He has at his command the possibilities of the introduction of practically all metallic elements into the weld material in any desired propor-

FIGURE 12—View of a 29 in. diameter shaft with new end welded on, typical of thermit repairs of this type.



tions; and these elements can be introduced by means of some metallic pieces which will be instantly melted in the reaction, or they may be introduced in the form of thermits—that is, combinations of the oxide of the metallic element with aluminum (see Table III). The efficiencies in reaction of all of these metallic oxides have been determined in a long series of experiments and, therefore, a combination of thermits will definitely produce a steel of a given analysis. By such means, we have at our control the tensile strength, the ductility, and the hardness of the resulting steels. The tensile strength can be varied from about 50,000 lb. per square strength can be varied from about 50,000 lb. per sq. in. to 110,000 lb. per sq. in., and the corresponding ductility from over 40 per cent elongation in 2 in. down to zero.

Table III—Formulae Showing the Aluminum Reduction of Various Oxides

Metallic oxides		Aluminum		Resultant slag		Resultant metal
$3Fe_3O_4$	+	$8Al$	=	$4Al_2O_3$	+	$9Fe$
Fe_2O_3	+	$2Al$	=	Al_2O_3	+	$2Fe$
$3Mn_3O_4$	+	$8Al$	=	$4Al_2O_3$	+	$9Mn$
Cr_2O_3	+	$2Al$	=	Al_2O_3	+	$2Cr$
WO_3	+	$2Al$	=	Al_2O_3	+	W
$3V_2O_5$	+	$10Al$	=	$5Al_2O_3$	+	$6V$
$3TiO_2$	+	$4Al$	=	$2Al_2O_3$	+	$3Ti$
$3NiO$	+	$2Al$	=	Al_2O_3	+	$3Ni$
MoO_3	+	$2Al$	=	Al_2O_3	+	Mo
$3SiO_2$	+	$4Al$	=	$2Al_2O_3$	+	$3Si$
B_2O_3	+	$2Al$	=	Al_2O_3	+	$2B$
$3Co_3O_4$	+	$8Al$	=	$4Al_2O_3$	+	$9Co$

We have now discussed the physical properties and the control of the analysis of the thermit steels, and all that remains is to speak of the degree of assurance that the operator has in making every weld a sound weld. Those familiar with the casting of ordinary steels and the importance of the control of the casting temperature must realize the difficulties we encounter where, in order to avail ourselves of the extremely high temperatures so necessary for the welding operation, we have to pour our castings at a temperature over 4000 degrees F. Thermit steels, however, have one very great advantage: they are perfectly deoxidized. In fact, all of them show a very slight aluminum content. Here again, the steel man is suspicious, because to him an excess of aluminum usually means trouble, but the troubles that he has experienced on this account may not be due to aluminum content in the steel, but rather to alumina which, because of the lower temperature of his steel, may remain entrapped. In thermit steels, the metal is as liqid as water. Great quantities of alumina are generated in the reaction and yet none is found in the steel itself. With such a liquid, the difference in specific gravity of the metal and the slag (alumina) causes an almost instantaneous, complete separation.

For these reasons, thermit steels do not have to be poured at low temperatures to cause them to solidify into dense, sound castings, and the presence or absence of defects in the steels will depend entirely upon the mold itself and the material from which it is made. For many years, this matter of mold construction was a real stumbling block in thermit welding. Many of the high-grade facings used in steel foundries were tried and many of the formulae on record in the Bureau of Standards; the real difficulty was the fusion of the clay content in the mold, the fusing point of all of the clays being well below the temperature of the thermit steel and the fusion itself being accompanied by the generation of more or less gas. The final solution of this problem was the selection of the best silica sands and

FIGURE 13—View showing thermit weld in the head of a heavy cast iron press.

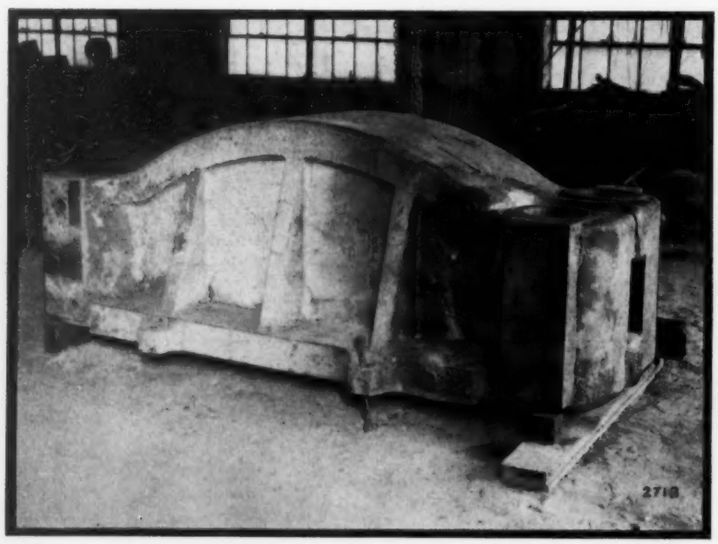
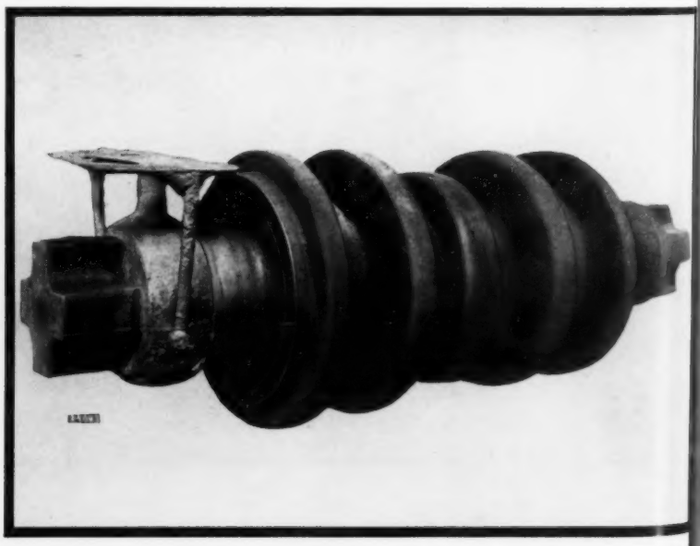


FIGURE 14—Worn wabblers on mill rolls may be replaced by welding on a new wabbler.



plastic clays, and the making of synthetic molding material containing a minimum of plastic clay so thoroughly mulled with the sand grains as to theoretically coat each grain with the thinnest possible layer of clay. Such a molding material not only generates much less gas when the thermit steel is brought into contact with it, but also remains so porous that the little gas generated easily passes out through the walls of the mold and not through the liquid thermit steel. Loose grains of sand trapped in the thermit steel will completely volatilize and, because of the possible formation of gas pockets on this account, they should, of course, be avoided, but this is a rather simple step in the regular routine of the welding process so that, with a suitable molding material and a reasonable amount of care, defective welds may be considered a thing of the past.

The elimination of defects in thermit welds was aided by a condition inherent in thermit welding, that is, that the thermit weld solidifies from the inside toward the outside; this, of course, tends to promote density and soundness in the weld itself. In the early days of welding before this fact was thoroughly realized, it was customary to use large risers with the idea that the shrinkage of the inner portions of the weld would have to be fed. These large risers were not only wasteful but actually harmful. It must be obvious why this shrinkage is so different from that in ordinary foundry practice; in the foundry, the heat from the molten steel passes out slowly through the mold, and solidification of the casting occurs first on the surface in contact with the mold and progresses toward the core of the casting, whereas in the welding operation the parts being welded act as enormous chills in the casting and extract the heat of the molten steel more rapidly from the center or core than from any other point. Freezing, therefore, occurs first approximately along the axis of the parts and radiates outward from this point. The realization of this fact and the conclusion that large risers were harmful rather than helpful introduced a radical change in the design of welds, which fortunately at the same time greatly lowered the cost of the welding operation. This decrease in cost in turn has increased the applications of welding until now it is more economical to weld almost anything in the steel mill than to substitute a new part.

In general, there are three uses for the thermit welding process in the steel mills:

1—The repair of broken parts, which may be indicated for economical reasons or by the saving in time in getting the mill or machine into operation again.

2—The building up of worn parts, which in many cases replaces the material worn off with one better suited to withstand the service.

3—The manufacture of new constructions or the making of old ones in a new way.

Until recently, the repair of broken parts was to the steel man's mind the only use for the thermit welding process. Those mills where break-downs were infrequent would call on outside thermit welders and felt that in their particular case a welding department was not necessary. The emergency value of this form of welding is, of course, admitted and we could recount thousands of cases where mills have resumed operations in only a fraction of the time that it would have taken to replace a part. The photographs reproduced throughout this paper give a fair idea of the possibilities of such emergency repairs.

As an example, the following list was made from the work done in one mill in a period of a few months. (Each item is mentioned only once although a number of each were welded): cast steel tin mill housing, 7½ in. driving axle, frame of open-hearth charging machine, open-hearth charging peel, 15 in. diameter roll neck, replacement of pods twisted off pinion, weld through 23½ in. diameter neck of nickel steel pinion, side guard post of manipulator rack, numerous table rolls, and 28 in. diameter single-throw crankshaft for steam engine of automatic reversing blooming mill.

And in another mill in about the same period: 132 in. cast steel plate mill housing, teeth replaced in numerous 40 in. herringbone pinions, cast iron roll of structural mill, replacement of entire wabbler end of steel roll, replacement of wabbler end of spindle of slab mill, repair of broken locomotive frame.

In other mills in about this same period, we see a long array of the usual repairs of mill housings, wabbler ends of rolls and pinions, numerous crankshafts, machine frames, universal drives, gear wheel teeth, and similar parts too numerous to mention in detail. In all cases, not only was there an enormous saving in time, but the repair cost was a very small fraction of the value of a new part.

With the introduction of welding departments in the steel mills, the character of the work has broadened and it is no longer restricted to emergency repairs. The replacement of metal worn off is one of the newer applications which has proved to be very profitable. In many such cases, it is very possible that the wearing qualities of the metal added in this manner will be a real improvement over these same qualities in a new piece; for instance, rolls, pinions, spindles, etc., must be designed

FIGURE 15—View of rolling mill pinion with new wabbler welded on by the thermit process.

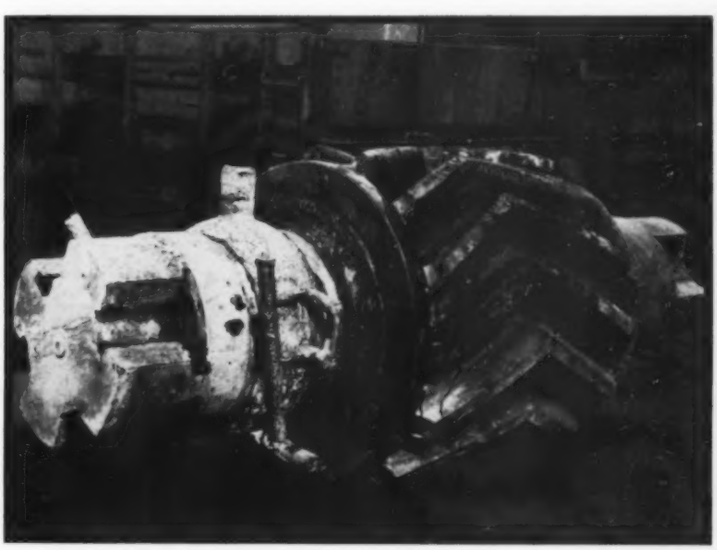


FIGURE 16—View showing a typically worn and battered joint in a crane runway rail.

for a toughness and strength which would preclude the use of steel having the maximum wear resistance, but it is perfectly feasible in the replacement of the worn pods of these parts to use a thermit which will produce a steel of any desired hardness. In practice, steels are selected which are so hard as not to be machinable and the weld can be made so true to size as not to require machining.

This welding process opens up a wide field and has greatly changed the methods of manufacture not only of the parts of machines used in the mill but also the products of the mill. It is perfectly feasible to make wabbler ends of a steel offering the greatest possible wear resistance and to thermit weld such wabbler ends to the necks of ordinary rolls. New ends for charging peels may be kept on hand and welded as required to replace other broken or worn ends. Thermit steels of extreme hardness may be cast on surfaces subject to wear or even in the bore of cylinders and, in fact, any part may by means of welding be designed to have different physical properties at various points; considerations of this kind lead to the making of parts with greatly prolonged operating life and eliminate expensive shut-downs.

The co-ordination of the various departments of steel mills in welding work is most important if fullest benefits are to be enjoyed. It is, of course, not feasible to have a number of independent welding departments in one plant, nor is it feasible for the various mill superintendents to keep in close touch with a central welding department. This question has been solved in certain mills by the organization of a reclamation department under a suitable head, who, together with the mill superintendent interested, has the final say as to which broken or worn parts should pass on to the scrap pile and which should be reclaimed. The mere existence of a welding department and experienced welders will not in itself effect the desired economies, and the installation of a co-ordinated reclamation department, or some suitable substitute, at present seems very important.

Increasing interest is being shown by steel mills and other plants in the welding of crane runway rail for heavy cranes. The advantages gained by doing away with joints in such rail are more or less obvious, including smoother crane operation, saving in damage to crane and crane structures, elimination of broken wheels, and reduction in maintenance of the runway rail itself. Also, in the case of collector rail, 100 per cent electrical conductivity is obtained.

Because in most cases crane runway rail is bolted direct to the girder, it was necessary for us to develop for this type of work a new design of weld with no collar under the base. This weld is shown in Figure 17. The weld has a riser on each side of the head rather than only one riser. This, of course, means the removal of two risers instead of one, but gives a stronger head weld and since the double flanged crane wheels ride the center of the rail, instead of the gauge side as in most railway work, assures better wearing qualities.

Molds are rammed in the same way as in any of our other rail welds. Their application to the rail is also identical. Both halves of the mold are the same as far as patterns are concerned and, therefore, only one pattern instead of the usual pair of patterns is required.

In order that the rail need be lifted as little as possible, mold boxes extend below the rail only $1\frac{1}{2}$ in. instead of the usual 2 in. This is made possible by the fact that there is no base collar on the weld. Besides reducing the quantity of molding material, the shorter mold box also assures better drying of the mold at that point. Stop plates are tack welded to the mold box at the gauge faces to prevent too much squeeze-up when tightening the top square clamp for mold box strut screw, if used. These plates automatically prevent

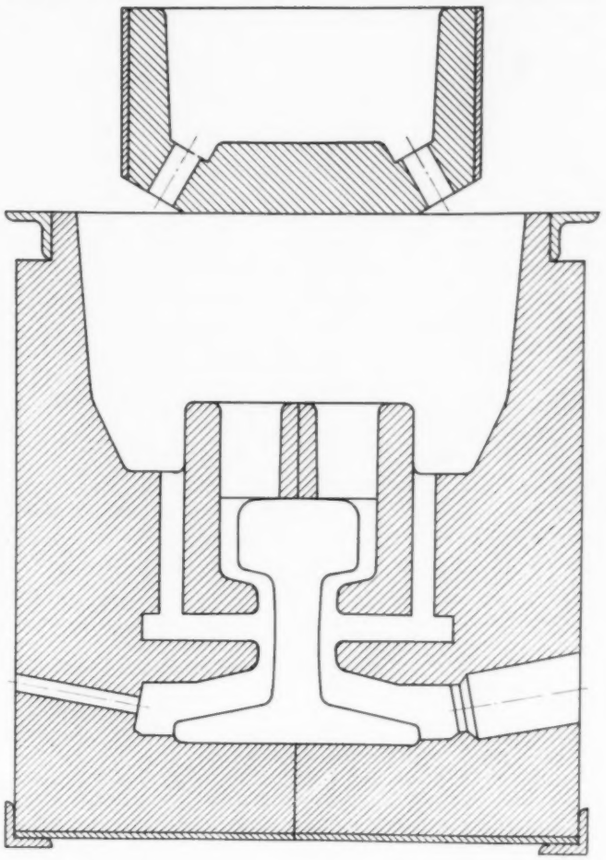


FIGURE 17—Diagram showing details of the method of welding crane rails by the thermit process.

FIGURE 18—View of equipment for thermit welding of crane rails.

excessive crushing of the mold collar and riser against the rail, regardless of how tightly the clamps are drawn up.

On all crane rail, a relatively high preheat is desirable to assure sound welds, especially as there is little danger of burning or over-heating the rail. Using the regular rail preheater, for example, 28–30 minutes is recommended for 105 lb. crane rail, while 45 minutes is required to properly preheat 175 lb. rail. This preheater is probably somewhat more efficient than the shop tank preheater, however, and where the latter is used, slightly longer preheating may possibly be necessary.

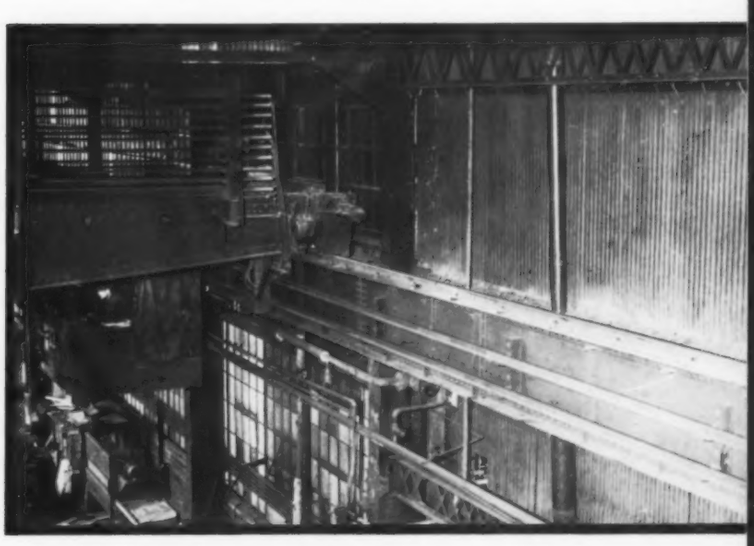
Welds may be stripped hot, using a blacksmith's hot-cutter to remove the risers and trim the side collars on the ball. This leaves a minimum of finishing and reduces finishing costs. Where the equipment is available, a cup grinder may be employed, otherwise our draw filing method is used. In no case should finishing be done with a rotary grinding wheel.

The thermit used on crane rail welding is of a special mixture designed to produce a steel with the same wearing qualities as the rail. This mixture is termed crane rail welding thermit.

Welding may be done either on the ground and the welded rail hoisted into position after the joints have been finished, or the work may be done up on the runway. The method employed will depend, of course, on conditions encountered in the plant where the job is to be done, or on the desires of the customer. In some of the newer buildings, there is ample room to work as a catwalk 3 ft. wide or more is provided along the runway. In other cases, where there is no catwalk, the runway is very close to the side of the building, and considerable inconvenience may result. Naturally, these conditions will affect rate of production, but as a rule of thumb, six to eight welds per eight hour day may be considered the average for a crew of four men.

It is usually only possible to preheat a single joint at a time. Therefore, a minimum amount of equipment for

FIGURE 19—View of continuously welded rail installed and in service on crane runway.



setting up two joints and preheating one at a time is all that is necessary. In case of a job involving an exceptionally large number of welds, however, additional equipment may be desirable.

Because of the varying conditions under which the work has been done, and the fact that only a relatively few installations have been made to date, no very definite figures as to the cost to the customer of crane rail welding are available. Indications are, however, that this cost will average in the neighborhood of $12.00–$15.00 per weld.

DISCUSSION

PRESENTED BY

W. R. PERSONS, *District Manager*, Lincoln Electric Company, Pittsburgh, Pennsylvania.

E. H. TURNOCK, Welding Rod Laboratory, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

H. O. WESTENDARP, JR., General Electric Company, Schenectady, New York.

W. R. PERSONS: On the subject of electrode coatings, I would like to make one comment. It is reasonably evident that we have not yet scratched the surface on the development of the proper type of coating for individual applications. I think there is a tendency on the part of many engineers to try to seize upon one general type of electrode as the answer to all their problems. I am confident that there is no such rod.

In the matter of developing electrodes for specific applications, we know from everyday experience that we can make reductions in total welding cost of as much as 50 per cent on given applications by changing the coating material.

I was very much impressed with Mr. Deppeler's remarks relative to the advisability of attempting to duplicate the physical properties of the steels in welding rather than duplicating chemical analysis. We are pretty well convinced that this is the right track, particularly in view of the fact that in attempting to duplicate chemical composition you may in a great many cases not wind up with the same type of deposited metal that you thought you were going to get. This results from the changes that take place in metal going across the arc.

E. H. TURNOCK: Mr. Deppeler has a long and enviable period of service to this industry, so we can all listen to what he has to advise with considerable benefit.

I heartily agree with Mr. Persons that one of the real troubles any man faces in using welding is to keep up to date with progress that is being made in electrodes. I believe we all face the necessity of discarding the idea of maintaining in the storeroom one type of electrode with which we expect to do all types of mild steel welding. It costs between $2.00 and $3.00 an hour to maintain a welder in a production welding shop. It is unsound supervision to fail to supply that welder with the suitable electrode and positioning equipment.

Mr. Deppeler in his paper brought out one point that is still an open one and subject to a difference of opinion, namely, fish eyes in the welded joint. I know he follows the theory, which has also been supported by Mr. Ronay of the Navy Testing Laboratory, that fish eyes occur because of a difference in grain structure in the successive passes of the weld. There is another school of thought, however, with which many of us are inclined to agree. We have found that wherever fish eyes occur in a tested tensile specimen it is not a question of grain structure but of a definite defect in the weld, either a gas hole or a slag inclusion. We have hunted rather religiously to run down the cause and our experience has pointed to a fundamental defect either in the electrode used or the technique of using it.

An interesting point to back up Mr. Deppeler's position is the fact that when you stress relieve you no longer find fish eyes. Our investigation shows the defect is still present but that stress relieving has probably modified the grain boundaries at the defect sufficiently to avoid a fish eye fracture.

H. O. WESTENDARP, JR. All thanks are due Mr. Deppeler for a most interesting and clear discussion of the problems of electrode design which lie behind all the performance characteristics with which the application engineer and the user are constantly concerned.

From the application stand-point the importance of concentricity can hardly be overestimated. Strict tolerance limits regarding eccentricity have, however, been established by users, and their experience has shown that uniform extruded type electrodes of entirely satisfactory concentricity can be obtained for either downhand or vertical and overhead. While it is true that the heavy currents used in downhand welding make uniformity particularly desirable, itis also true that with the heavier thickness of coating used on these electrodes a given variation, of say .001 in., represents a much smaller percentage of the total coating thickness and consequently produces much less disturbance than would the same variation in the thin ner coating of a vertical and overhead rod.

With regard to the use of straight vs. reverse polarity on heavily coated electrodes, there is apparently a trend toward straight polarity. Some manufacturers' lines show a predominance of straight polarity types. Quite possibly this is due in large measure to the increasing use of alternating current, particularly for heavy flat-position work. While the underlying reasons may be obscure to any but an electrode designer, the fact is that electrodes designed for alternating current give better performance on straight polarity than on reverse polarity, when used with direct current.

Mr. Deppeler's comments on the relationship between arc voltage, flux thickness, penetration and pick-up touch on matters of extreme importance to the user. It is not entirely clear why a bare wire can be used to obtain less pick-up, since the general impression is that bare wires show greater penetration than heavily coated wires. Penetration, of course, is affected by melting rate, travel speed, and other factors which might obscure

(*Please turn to page 75*)

COKE and BY-PRODUCT YIELDS from Various Coals*

By J. D. DAVIS, *Senior Fuel Chemist*

COAL CARBONIZATION DEPARTMENT

UNITED STATES BUREAU OF MINES, PITTSBURGH, PA.

Presented before A. I. S. E. Annual Convention, Pittsburgh, Pennsylvania, September 26-29, 1939

▲ TEN years ago the Bureau of Mines, at the request of the American Gas Association, began a survey of the gas-, coke-, and by-product-making properties of American coals which had for its main purpose determination of the yields and quality of carbonization products at low, medium, and high temperatures from American coals usable in the coke- and gas-making industries. Because of the empirical nature of the carbonizing process, design of suitable carbonization test apparatus for the work was a difficult problem. The scale of test was required to be small enough to insure precise control so that reproducible results could be obtained and to be large enough to yield enough products for complete chemical and physical examination. Once a test method and procedure were adopted, it also was required that no radical changes be introduced because in the survey it was planned to measure the carbonizing properties of all coals by the same procedure so that the results would be strictly comparable. No two coke plants will give exactly the same yields of products from a given coal, and gas retort plants will give still different yields. The method of test adopted is known as the Bureau of Mines-American Gas Association method. Sixty coals have now been tested by this method.

CARBONIZATION TEST PROCEDURE

The apparatus used and the procedure followed in the Bureau of Mines-American Gas Association carbonization test method have been described in detail elsewhere.[1] A brief statement of the method will serve the present purpose. The charges are sealed by welding into cylindrical sheet-steel retorts with outlet pipes for connection to a by-product recovery and scrubbing train. The charges thus prepared are lowered quickly into an electric furnace which has been heated previously to the carbonizing temperature desired. After the outlet pipe is connected to the by-product train (about 15 seconds are required to make the connection) the temperature of the furnace is kept constant automatically by a thermo-electric controller until carbonization is complete. Completion of a test is best indicated by a sudden drop in the rate of gas make. Tar, liquor, light oil, hydrogen sulphide, and ammonia are collected in the by-product train by conventional methods, except that the gas does not bubble through liquids at any point, so that back pressure on the walls of the retort is kept at a minimum. The gas is metered by a standard wet-test meter, and a composite sample is taken automatically; its heating value and specific gravity are recorded continuously. At the end of a test the retort is removed from the furnace, capped, and allowed to cool, with exclusion of air from the coke. The bottom is then removed by cutting with a cold-chisel, and the coke is discharged and weighed. Chemical and physical properties of the carbonization products are determined by methods of the American Society for Testing Materials[2] and the American Gas Association[3] wherever these methods apply.

PROCUREMENT OF SAMPLES AND SCOPE OF TEST WORK

Samples of coal for test usually are submitted by coal operators and large consumers, but requests for tests by other responsible parties receive the same consideration. Coals are considered in the order of receipt of requests. They are accepted provided the parties interested will agree to pay the freight on the samples and the cost of sampling, and provided that the coals are suitable for inclusion in the survey.

All samples are taken from the face of the coal in the mine under the supervision of a Bureau of Mines engi-

*Published by permission of the Director, Bureau of Mines.

neer. Two to five channel samples are taken (depending on the size of the mine) and analyzed to show how the coal varies in the mine; then a location is selected for taking the carbonizing sample and a column of coal across the bed for microscopic analysis. Approximately two tons of coal are required for the carbonizing sample which is so taken as to represent all the merchantable coal in the bed; the solid column sample (about 12 in. by 12 in. cross section) includes all the coal in the bed. Immediately after the carbonizing sample is cut down it is placed in air-tight steel drums so that it can be stored and shipped to the laboratory with minimum oxidation and loss of moisture. The column is packed carefully in a wood box to prevent breakage of the coal during shipment.

When the carbonizing sample is received at the laboratory it is crushed so that all of it will pass a ¼ in. screen and sampled into air-tight steel drums, each holding enough coal for one carbonization test. The following carbonization tests are made:

1. Tests in duplicate at 500, 600, 700, 800, and 900 degrees C. in 80 to 90 pound charges.
2. Tests in duplicate at 800, 900, and 1000 degrees C. in 180 to 200 pound charges.
3. Two blend tests at 900 degrees C. on 180 to 200 pound charges containing 20 per cent of low-volatile coal, and two at 900 degrees C. with the charge weighing the same but containing 30 per cent of low-volatile coal.
4. Two tests at 800 degrees C. on 180 to 200 pound charges previously subjected to controlled oxidation at moderate temperatures.

The yields and qualities of carbonization products are determined for all tests, and a material balance usually totaling 99.0 to 100 per cent of the charge is obtained.

Examination of the coal includes the proximate and ultimate analysis, heating value, softening temperature of the ash, and forms of sulphur. A microscopic analysis is made of the column sample indicating the types of coal present and their origin. Also, the plastic and expanding properties are determined and laboratory-scale high and low temperature assays are made. In short, all properties of the coal believed to affect its coke- and gas-making properties are investigated.

The purpose of this paper is to show the effect of rank and type of coal and the carbonizing temperature on the yields and quality of carbonization products obtained by the BM-AGA test method. The effect of weathering and relationship of expanding properties of coals to damage of industrial carbonizing equipment are also discussed.

EFFECT OF RANK OF COAL ON THE YIELDS AND QUALITIES OF PRODUCTS

Table I gives the proximate and ultimate analyses of coals considered under this heading, the grouping being according to rank. The low-, medium-, and high-volatile A groups have average volatile matter contents about mid-way in the range of rank in question. Only two high-volatile B coals were available. The results of carbonization tests on these coals indicate what may be expected of the group, but cannot be considered truly representative. The Lower Sunnyside coal (No. 19) has special carbonizing properties, not dependent on rank, which will be discussed later.

The ash and sulphur contents of these coals are low for the most part, and the softening temperatures of the ashes, except for coals 23, 10, and 19, are medium to high. They are of suitable grade, therefore, for making coke and gas. The ash content of coal 10 is somewhat high, but the writer understands that it can be brought within specifications by washing.

Table II gives the yields of carbonization products obtained at 500 degrees C. (932 degrees F.) and Table III the yields obtained at 900 degrees C. (1,652 degrees F.) in the BM-AGA 13-in. retort, which holds approximately 90 lb. of coal. The tables give results on the basis of coal as received and also on the basis of moisture- and ash-free coal. Averages for each group on both bases are also given. Theoretically the moisture- and ash-free results are best adapted to show the effect of rank on the yields of carbonization products; they are independent of the grade of the coal as determined by its impurities. Yields of products on the as-received basis are of more practical interest to the engineer because the coal he charges into his coke ovens is in this state.

For both carbonizing temperatures the yield of coke increases with the rank of the coal at the expense of volatile products, the main decrease in volatile products being in the tars, light oils, and liquors. The yields of gas on the volume basis in the 900 degrees C. tests do not vary greatly with rank, but on the weight basis and that of heating value per lb. of coal carbonized there is a definite decrease in the yield as the rank of the coal increases. Exceptionally high yields of gas, tar, and light oils were obtained from coal 19 in the 900 degree C. tests, that is, 11,930 cu. ft. of gas (3640 Btu. per pound of coal), 15.8 gallons of tar, and 3.73 gallons of light oil per ton of moisture- and ash-free coal. This coal is particularly rich in resins which, at low temperatures, distill for the most part as tar. At high temperatures some of these tars crack, forming light oils and gas. An exceedingly high yield of tar (30.3 gallons per ton, moisture- and ash-free basis) was obtained at 500 degrees C., but the yields of gas and light oil were not as much higher than coal 10 yields as they were in the 900 degrees C. tests. The yields of ammonium sulphate increase with decreasing rank of the coals for both carbonizing temperatures. The nitrogen content of the coals (Table I) does not vary with their rank, but the liquor content increases with decreasing rank and it is known that high sulphate yields are promoted by carbonization in water vapor. The yields of sulphate in the 900 degree C. tests are of comparative value only, showing the relative yields from different coals as carbonized in the BM-AGA retorts. The steel walls of the retorts decompose ammonia more rapidly than coke oven refractory walls at that temperature. Yields of ammonia obtained at 700 to 800 degrees C. in the retorts approach more closely to industrial yields as will be shown later.

Tables IV and V show the physical properties of the cokes made at 500 and 900 degrees C., respectively. Probably the most significant figures to use in comparing cokes made by the BM-AGA method are the apparent specific gravity, the 1½ in. shatter index, and the 1 in. tumbler index. Pocahontas No. 4 coal (sample No. 23) does not seem to contain enough volatile matter to produce coke of strength representative of low-volatile

TABLE 1

Analyses of Coals*

Coal No.	Description and origin	Condition **	Proximate, per cent			Ultimate, per cent						Heating value, Btu. per lb.	Softening temperature of ash, degrees F.
			Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur		
Low-volatile													
23	Pocahontas No. 4 bed, Consolidation No. 251 Mine, McDowell County W. Va.	1	0.8	15.4	79.0	4.8	4.3	86.7	1.1	2.6	0.5	14,870	2,370
		2	...	15.5	79.6	4.9	4.2	87.4	1.1	1.9	0.5	14,990	.....
		3	...	16.3	83.7	....	4.4	91.8	1.2	2.1	0.5	15,760	.....
26	Sewell bed, Cranberry No. 3 Mine, Raleigh County, W. Va.	1	1.3	20.8	75.8	2.1	4.9	86.8	1.7	3.7	0.8	15,190	2,540
		2	...	21.1	76.8	2.1	4.8	88.0	1.7	2.6	0.8	15,400	.....
		3	...	21.5	78.5	....	4.9	89.9	1.8	2.6	0.8	15,730	.....
48	Lower Kittanning bed (washed), No. 72 Mine, Cambria County, Pa.	1	2.9	16.1	75.3	5.7	4.6	82.8	1.4	4.7	0.8	14,300	2,910+
		2	...	16.5	77.7	5.8	4.4	85.2	1.4	2.4	0.8	14,720	.....
		3	...	17.6	82.4	....	4.7	90.5	1.5	2.5	0.8	15,630	.....
51	Upper Kittanning bed (washed), No. 73 Mine, Cambria County, Pa.	1	2.2	17.3	72.0	8.5	4.5	80.2	1.4	4.2	1.2	13,980	2,660
		2	...	17.6	73.7	8.7	4.4	81.9	1.4	2.4	1.2	14,280	.....
		3	...	19.3	80.7	....	4.8	89.8	1.5	2.6	1.3	15,650	.....
41	Beckley bed, Winding Gulf No. 1 Mine, Raleigh County, W. Va.	1	2.3	17.9	76.0	3.8	4.6	85.3	1.4	4.5	0.4	14,820	2,919+
		2	...	18.3	77.8	3.9	4.5	87.3	1.4	2.5	0.4	15,160	.....
		3	...	19.1	80.9	....	4.7	90.9	1.4	2.6	0.4	15,780	.....
Medium-volatile													
27	Sewell bed, Summerlee Mine, Fayette County, W. Va.	1	1.9	26.5	69.2	2.4	5.2	84.6	1.6	5.7	0.5	14,970	2,730
		2	...	27.0	70.5	2.5	5.1	86.2	1.6	4.1	0.5	15,250	.....
		3	...	27.7	72.3	....	5.2	88.4	1.7	4.2	0.5	15,640	.....
5	60 per cent Davis bed, Arnold Mine, Garrett County, Md., and 40 per cent Pittsburgh bed, Warden Mine, Allegheny County, Pa.	1	1.5	27.7	63.3	7.5	...	....	...	....	1.2	14,070	2,740
		2	...	28.1	64.3	7.6	...	....	...	....	1.2	14,280	.....
		3	...	30.4	69.6	....	...	....	...	....	1.3	15,450	.....
8	Mary Lee bed (washed), Flat Top Mine, Jefferson County, Alabama	1	4.2	27.6	59.9	8.3	5.1	76.2	1.6	8.0	0.8	13,550	2,810
		2	...	28.8	62.5	8.7	4.8	79.6	1.6	4.5	0.8	14,140	.....
		3	...	31.5	68.5	....	5.3	87.1	1.8	4.9	0.9	15,490	.....
25	60 per cent Pittsburgh bed, Consolidation No. 63 Mine, Marion County, W. Va., and 40 per cent Pocahontas No. 4 bed, Consolidation No. 251 Mine, McDowell County, W. Va.	1	1.4	28.3	64.8	5.5	5.0	81.2	1.5	6.2	0.6	14,330	2,450
		2	...	28.7	65.7	5.6	4.9	82.4	1.5	5.0	0.6	14,540	.....
		3	...	30.3	69.7	....	5.2	87.2	1.6	5.4	0.6	15,400	.....
55	Sewell bed, Wyoming Mine, Wyoming County, W. Va.	1	1.6	21.8	73.7	2.9	4.9	85.8	1.4	4.3	0.7	14,950	2,510
		2	...	22.1	74.9	3.0	4.8	87.2	1.5	2.8	0.7	15,200	.....
		3	...	22.8	77.2	....	5.0	89.9	1.5	2.8	0.8	15,670	.....
High-volatile A													
28	Pittsburgh bed, Warden Mine, Allegheny County, Pa.	1	1.8	35.1	57.7	5.4	5.3	79.0	1.6	7.8	0.9	14,140	2,740
		2	...	35.7	58.8	5.5	5.2	80.5	1.6	6.3	0.9	14,410	.....
		3	...	37.8	62.2	....	5.5	85.2	1.7	6.6	1.0	15,240	.....
44	Powellton A bed, No. 9 Mine, Kanawha County, W. Va.	1	1.8	32.4	62.9	2.9	5.4	83.0	1.4	6.5	0.8	14,790	2,650
		2	...	33.0	64.0	3.0	5.3	84.5	1.5	4.9	0.8	15,070	.....
		3	...	34.0	66.0	....	5.4	87.1	1.5	5.2	0.8	15,530	.....
46	Eagle bed, No. 3 Mine, Logan County, W. Va.	1	1.6	31.9	61.0	5.5	5.1	80.6	1.6	6.6	0.6	14,270	2,910
		2	...	32.4	62.0	5.6	5.0	81.9	1.6	5.2	0.7	14,510	.....
		3	...	34.3	65.7	....	5.3	86.8	1.7	5.5	0.7	15,370	.....
43	Dorothy bed, No. 10 Mine, Kanawha County, W. Va.	1	2.0	34.5	59.4	4.1	5.4	81.1	1.4	7.4	0.6	14,470	2,910+
		2	...	35.2	60.7	4.1	5.3	82.8	1.4	5.8	0.6	14,760	.....
		3	...	36.7	63.3	....	5.5	86.3	1.5	6.0	0.7	15,390	.....
40	Lower Cedar Grove bed, Junior Mine, Mingo County, W. Va.	1	1.8	35.3	58.6	4.3	5.4	80.7	1.5	7.5	0.6	14,400	2,800
		2	...	35.9	59.7	4.4	5.3	82.2	1.5	6.0	0.6	14,670	.....
		3	...	37.6	62.4	....	5.6	85.9	1.6	6.2	0.7	15,340	.....
High-volatile B													
10	No. 6 bed, Orient No. 1 Mine, Franklin County, Illinois	1	7.9	32.1	47.7	12.3	5.1	65.5	1.4	14.9	0.8	11,540	2,360
		2	...	34.9	51.7	13.4	4.6	71.2	1.5	8.4	0.9	12,530	.....
		3	...	40.3	59.7	....	5.3	82.2	1.7	9.8	1.0	14,460	.....
19	Lower Sunnyside bed, Columbia Mine, Carbon County, Utah	1	4.6	38.8	50.6	6.0	5.7	72.9	1.5	12.9	1.0	13,030	2,440
		2	...	40.6	53.1	6.3	5.4	76.4	1.6	9.2	1.1	13,660	.....
		3	...	43.4	56.6	....	5.8	81.5	1.7	9.9	1.1	14,580	.....

*Analyses by H. M. Cooper, chemist, Bureau of Mines.
**1: Sample as received; 2: sample moisture-free; 3: sample moisture- and ash-free.

coals. However, it is used industrially in blending, as are other coals of the same volatile-matter content; therefore its carbonizing properties should be included in discussions of low-volatile coals. If this coal is excluded in making the averages the 1½ in. shatter indexes for the 500 and 900 degree C. tests, respectively, become 96.2 and 80.7 per cent; the corresponding 1 in. tumbler indexes become 63.2 and 65.6 per cent. Two low-volatile coals and one high-volatile B did not produce coherent coke in the 500 degree C. tests, because these coals did not become plastic enough to cohere under the slow carbonizing rate at this temperature. The carbonizing time is 33 hours compared to 7½ for the 900 degree C. tests. It may be concluded that, with the foregoing exceptions, the strength of the coke increases with increasing rank of the coal. The density (apparent specific gravity) of the coke made at 900 degrees C. increases regularly with increasing rank of the coal, but this relationship does not hold for cokes made at 500 degrees C.

Tables VI and VII show the chemical and physical properties of gases made in the 500 and 900 degree C. tests. The specific gravity and the oxides of carbon increase with decreasing rank of the coal, because the oxygen content of the coals increases in about the same proportion. The heating value per cu. ft. and per lb. of coal carbonized, the illuminants, and methane and ethane tend to increase to a maximum in the high-

TABLE II

Yields of Carbonization Products, as Carbonized, and Ash- and Moisture-free Bases, Tests at 500 Degrees C.

Coal No.	Condition **	Yields, per cent by weight of coal							Yields per ton of coal				Gas, Btu. per lb. of coal
		Coke	Gas	Tar	Light oil	Ammonia	Liquor	Total	Gas, cu. ft.	Tar, gallons	Light oil, gallons	$(NH_4)_2SO_4$ lb.	
Low-volatile													
23	1	93.0	4.2	1.6	0.12	0.05	1.3	100.2	2,100	3.5	0.37	4.3	900
23	2	93.4	4.4	1.7	0.13	0.05	0.5	....	2,220	3.7	0.39	4.6	950
26	1	86.5	5.3	3.5	0.11	0.02	3.3	99.1	2,500	8.0	0.32	2.5	1,080
26	2	87.4	5.5	3.6	0.11	0.02	2.1	....	2,590	8.3	0.33	2.6	1,120
48	1	89.7	4.3	1.4	0.16	0.01	4.1	99.7	2,200	3.2	0.47	1.1	950
48	2	91.9	4.7	1.5	0.18	0.01	1.3	....	2,410	3.5	0.51	1.2	1,040
51	1	90.0	4.7	1.9	0.17	0.03	3.5	100.3	2,400	4.2	0.53	3.4	1,040
51	2	91.3	5.3	2.1	0.19	0.03	1.5	....	2,690	4.7	0.59	3.8	1,160
41	1	88.9	4.5	2.8	0.19	0.03	3.3	99.7	2,350	6.4	0.59	3.0	1,010
41	2	90.6	4.8	3.0	0.20	0.03	1.1	....	2,500	6.8	0.63	3.2	1,080
Average	1	89.6	4.6	2.2	0.15	0.03	3.1	99.7	2,310	5.1	0.46	2.9	1,000
Average	2	90.9	4.9	2.4	0.16	0.03	1.3	99.5	2,480	5.4	0.49	3.1	1,070
Medium-volatile													
27	1	82.0	6.2	6.1	0.22	0.03	3.2	97.8	2,950	14.6	0.67	3.6	1,320
27	2	84.0	6.5	6.4	0.23	0.03	1.4	....	3,080	15.3	0.70	3.8	1,380
5	1	83.8	5.4	4.2	0.36	0.01	4.0	97.8	2,400	10.2	1.13	2.4	1,040
5	2	83.9	5.9	4.6	0.40	0.01	2.7	....	2,640	11.2	1.24	2.6	1,140
8	1	81.2	6.2	5.1	0.61	0.02	6.6	99.7	2,500	12.3	1.90	2.5	1,070
8	2	83.4	7.1	5.8	0.70	0.02	2.7	....	2,860	14.1	2.17	2.9	1,220
25	1	83.0	5.4	6.3	0.18	0.03	4.1	99.0	2,400	14.9	0.55	4.4	1,050
25	2	83.4	5.8	6.7	0.19	0.03	2.9	....	2,560	15.9	0.59	4.7	1,120
55	1	86.6	4.8	3.9	0.23	0.03	3.1	98.7	2,400	9.0	0.73	2.5	1,060
55	2	87.6	5.0	4.1	0.24	0.03	1.6	....	2,510	9.4	0.76	2.6	1,110
Average	1	83.3	5.6	5.1	0.32	0.02	4.2	98.5	2,530	12.2	1.00	3.1	1,110
Average	2	84.5	6.1	5.5	0.35	0.02	2.3	99.0	2,730	13.2	1.09	3.3	1,190
High-volatile A													
28	1	76.4	6.1	10.5	0.35	0.02	5.9	99.3	2,650	24.5	1.12	4.4	1,250
28	2	76.5	6.6	11.3	0.38	0.02	4.4	....	2,860	26.4	1.21	4.7	1,350
43	1	77.0	5.8	10.4	0.32	0.03	4.9	98.5	2,550	25.0	1.03	4.5	1,190
43	2	77.7	6.2	11.1	0.34	0.03	3.1	....	2,720	26.6	1.10	4.8	1,270
44	1	78.5	6.3	9.3	0.40	0.04	4.9	99.4	2,800	21.9	1.25	5.1	1,310
44	2	79.3	6.6	9.8	0.42	0.04	3.3	....	2,940	23.0	1.31	5.4	1,380
46	1	79.3	5.7	8.7	0.40	0.02	5.3	99.4	2,550	20.6	1.28	4.0	1,160
46	2	79.5	6.1	9.4	0.43	0.02	4.0	....	2,740	22.2	1.38	4.3	1,250
40	1	76.5	6.0	10.7	0.39	0.03	5.9	99.5	2,550	25.5	1.24	4.4	1,200
40	2	76.9	6.4	11.4	0.42	0.03	4.4	....	2,720	27.2	1.32	4.7	1,280
Average	1	77.5	6.0	9.9	0.37	0.03	5.4	99.2	2,620	23.5	1.18	4.5	1,220
Average	2	78.0	6.4	10.6	0.40	0.03	3.8	99.2	2,800	25.1	1.26	4.8	1,310
High-volatile B													
10	1	72.5	5.2	6.8	0.28	0.01	14.5	99.3	2,100	15.6	0.88	3.9	850
10	2	75.7	6.5	8.5	0.35	0.01	8.3	....	2,630	19.5	1.10	4.9	1,070
19	1	70.3	6.8	11.1	0.41	0.02	10.6	99.2	2,500	26.9	1.30	5.4	1,080
19	2	72.0	7.6	12.4	0.46	0.02	6.7	....	2,800	30.1	1.45	6.0	1,210
Average	1	71.4	6.0	9.0	0.35	0.02	12.6	99.3	2,300	21.3	1.09	4.7	965
Average	2	73.9	7.1	10.5	0.41	0.02	7.5	100.2	2,720	24.8	1.28	5.5	1,140

**1: coal, as carbonized; 2: coal, ash- and moisture-free.

volatile A group of coals as the rank decreases and to decrease in the high-volatile B group. The best yields of gas are obtained from high-volatile A coals; they often are called gas coals for this reason.

Tables VIII and IX give the properties of the tars. Except for the tar acid and aromatic content there appears to be no consistent variation in the composition of the tars with rank of the coal. An increasing tar acid content with decreasing rank of the coal is to be expected because tar acids are stable oxygenated compounds and the oxygen content of coal increases regularly with decreasing rank. This tendency in tar acid content is observable in both the low- and high-temperature tars. If one calculates the yield of tar acids per ton of coal from the composition of the tar and the yield in gallons per ton of coal (Table II) he obtains a better indication of the effect of rank than from the composition of the tar alone. For example, in the tests at 500 degrees C. the yields of tar acids for low-volatile, medium-volatile, high-volatile A, and high-volatile B coals were 0.3, 2.0, 3.9, and 4.9 gallons per ton, respectively. The aromatic content of the tar decreases with decreasing rank of the coal.

Tables X and XI show the composition of the light oils. It appears that there is no consistent variation of the composition of these oils with the rank of the coal;

TABLE III

Yields of Carbonization Products, as Carbonized and Ash- and Moisture-free Bases, Tests at 900 Degrees C.

Coal No.	Condition **	Yields, per cent by weight of coal							Yields, per ton of coal				Gas Btu. per lb. of coal.
		Coke	Gas	Tar	Light oil	Ammonia	Liquor	Total	Gas, cu. ft.	Tar, gallons	Light oil, gallons	$(NH_4)_2SO_4$ lb.	
Low-volatile													
23	1	85.8	11.1	1.2	0.33	0.14	1.5	100.1	10,850	2.4	0.91	12.1	2,620
23	2	85.8	11.8	1.3	0.35	0.15	0.7	.....	11,490	2.5	0.96	12.8	2,780
26	1	79.9	12.0	3.0	0.51	0.23	3.6	99.2	10,600	6.2	1.42	21.4	2,880
26	2	80.5	12.4	3.1	0.53	0.24	2.4	.....	10,970	6.4	1.47	22.2	2,980
48	1	82.0	11.1	1.6	0.46	0.13	4.8	100.1	10,250	3.2	1.24	13.1	2,670
48	2	83.5	12.1	1.8	0.50	0.14	2.1	.....	11,220	3.5	1.36	14.3	2,920
51	1	82.7	11.3	1.9	0.50	0.20	3.4	100.0	10,100	3.7	1.37	16.7	2,630
51	2	83.1	12.7	2.1	0.56	0.22	1.3	.....	11,310	4.1	1.53	18.7	2,950
41	1	82.2	11.0	2.5	0.53	0.18	3.6	100.0	10,600	5.0	1.47	16.2	2,760
41	2	83.5	11.7	2.7	0.56	0.19	1.4	.....	11,290	5.3	1.57	17.3	2,940
Average	1	82.5	11.3	2.0	0.47	0.18	3.4	99.9	10,480	4.1	1.28	15.9	2,710
Average	2	83.3	12.1	2.2	0.50	0.19	1.6	99.9	11,260	4.4	1.38	17.1	2,910
Medium-volatile													
27	1	75.4	13.5	5.2	0.74	0.19	4.1	99.1	10,800	10.5	2.05	17.5	3,070
27	2	76.3	14.1	5.4	0.77	0.20	2.3	.....	11,280	11.0	2.14	18.3	3,210
5	1	74.8	14.1	5.8	0.47	0.17	5.0	100.3	10,200	11.9	1.33	17.1	3,090
5	2	74.0	15.5	6.4	0.52	0.19	3.8	.....	11,210	13.1	1.46	18.8	3,400
8	1	71.9	13.7	5.8	0.51	0.18	6.1	98.2	9,900	11.5	1.40	18.3	2,710
8	2	72.8	15.7	6.6	0.58	0.21	2.2	.....	11,310	13.1	1.60	20.9	3,100
25	1	74.8	13.6	5.2	0.70	0.18	4.6	99.1	10,250	11.1	1.99	21.0	2,930
25	2	74.6	14.5	5.6	0.75	0.19	3.4	.....	10,950	11.9	2.13	22.4	3,130
55	1	79.5	11.7	3.8	0.68	0.18	3.5	99.4	10,600	7.7	1.86	15.9	2,900
55	2	80.2	12.3	4.0	0.71	0.19	2.0	.....	11,100	8.1	1.95	16.6	3,040
Average	1	75.3	13.3	5.2	0.62	0.18	4.7	99.3	10,350	10.5	1.73	18.0	2,940
Average	2	75.6	14.4	5.6	0.67	0.20	2.7	99.2	11,170	11.4	1.86	19.4	3,180
High-volatile A													
28	1	68.3	14.5	8.3	0.96	0.08	6.9	99.0	10,450	17.4	2.71	16.7	3,210
28	2	67.8	15.6	8.9	1.03	0.09	5.5	.....	11,260	18.8	2.92	18.0	3,460
43	1	70.0	15.5	7.1	1.17	0.16	5.7	99.6	10,950	14.2	3.20	21.4	3,310
43	2	70.2	16.5	7.6	1.25	0.17	3.9	.....	11,660	15.1	3.41	22.8	3,530
44	1	71.1	15.2	7.1	1.16	0.20	4.7	99.5	11,000	14.3	3.17	19.4	3,310
44	2	71.6	15.9	7.5	1.22	0.21	3.0	.....	11,540	15.0	3.33	20.4	3,470
46	1	71.6	14.3	6.4	1.12	0.23	5.5	99.2	10,550	12.8	3.10	18.8	3,160
46	2	71.2	15.4	6.9	1.21	0.25	4.2	.....	11,360	13.8	3.34	20.2	3,400
40	1	69.1	16.2	6.7	1.26	0.13	6.2	99.6	10,850	13.8	3.50	18.6	3,430
40	2	69.0	17.3	7.1	1.34	0.14	4.7	.....	11,560	14.7	3.73	19.8	3,650
Average	1	70.0	15.1	7.1	1.13	0.16	5.8	99.3	10,760	14.5	3.14	19.0	3,280
Average	2	70.0	16.1	7.6	1.21	0.17	4.3	99.4	11,480	15.5	3.35	20.2	3,500
High-volatile B													
10	1	64.1	16.3	4.3	0.86	0.06	14.2	99.8	9,900	8.9	2.38	19.8	2,650
10	2	65.3	20.4	5.4	1.08	0.08	7.9	.....	12,410	11.2	2.98	24.8	3,320
19	1	62.0	19.0	6.7	1.22	0.16	10.6	99.7	10,700	14.1	3.36	27.1	3,330
19	2	62.8	21.3	7.5	1.36	0.18	6.7	.....	11,930	15.8	3.73	30.3	3,640
Average	1	63.1	17.7	5.5	1.04	0.11	12.4	99.9	10,300	11.5	2.87	23.5	2,990
Average	2	64.1	20.9	6.5	1.22	0.13	7.3	100.2	12,190	13.5	3.37	27.6	3,520

**1: coal, as carbonized; 2: coal, ash- and moisture-free.

in fact, the variation for individual coals of a given rank group is about as great as that between the averages for the different groups. On comparing the 500 degree C. light oils with those produced at 900 degrees C. it is clear that temperature of carbonization has a pronounced effect on their composition. The 900 degree C. light oils are much richer in aromatic compounds than those produced at 500 degrees C. and poorer in paraffins and olefins.

EFFECT OF TYPE OF COAL ON CARBONIZING PROPERTIES

In connection with the petrographic analyses made on all coals of the Bureau of Mines survey of the carbonizing properties of American coals, layers representing splint and bright coal types are segregated from the column sample of solid coal, analyzed, and tested for yields of carbonization products by the Fischer low-temperature assay. Results obtained on the splint and bright layers from Pond Creek bed high-volatile A coal[4] will serve to illustrate differences that may be noted in the properties of these two types of coal from the same bed. Figures 1 and 2, respectively, show bright and splint coal under the microscope at a magnification of 200 diameters. The illustrations were made by photographing exceedingly thin translucent sections cut from the coal. Splint is opaque compared to bright coal and usually contains more spores—large crinkled spores characteristic of the type. The original plant matter from which splint coal was formed was a heterogeneous mixture of plant remains, whereas bright coal was formed mainly from wood.

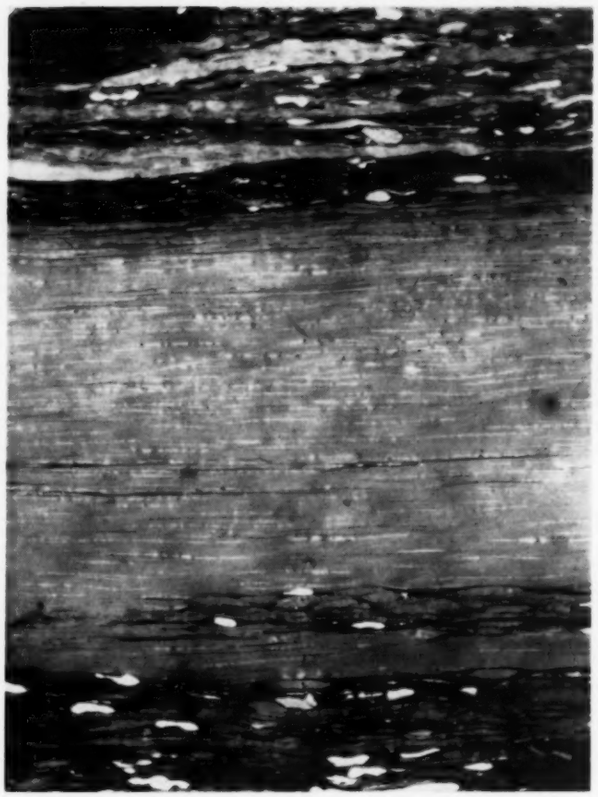


FIGURE 1—Section of bright coal (x 200).

TABLE IV

Physical Properties of Coke, 500 Degrees C. Tests

Coal No.	True specific gravity	Apparent specific gravity	Cells, per cent	Shatter test, cumulative per cent upon				Tumbler test, cumulative per cent upon			
				2-in. screen	1½-in. screen	1-in. screen	¼-in. screen	2-in. screen	1½-in. screen	1-in. screen	¼-in. screen
Low-volatile											
23	1.44	0.83	42.4	73.0	76.2	78.5	84.8	27.2	36.0	39.1	39.8
26	1.45	0.71	51.0	93.0	96.2	97.4	98.6	43.0	62.7	64.5	65.7
48	1.43			Coke too weak to test (granular)							
51	1.45			Coke too weak to test (granular)							
41	1.41	0.75	46.8	93.3	96.2	97.0	98.3	40.1	59.2	61.8	62.6
Average	1.44	0.76	46.7	86.4	89.5	91.0	93.9	36.8	52.6	55.1	56.0
Medium-volatile											
27	1.46	0.76	47.9	86.0	95.3	96.9	98.3	50.5	65.6	68.7	69.7
5	1.45	0.74	48.7	94.8	96.1	97.2	98.4	54.2	64.6	66.2	67.1
8	1.47	0.74	49.7	92.3	95.0	96.3	97.7	34.5	51.4	56.1	57.8
25	1.48	0.82	44.7	92.5	95.6	96.2	97.8	32.8	51.0	55.3	56.3
55	1.43	0.77	46.2	92.3	96.1	97.2	98.5	44.1	64.3	68.6	70.5
Average	1.46	0.77	47.4	91.6	95.6	96.8	98.1	43.2	59.4	63.0	64.3
High-volatile A											
28	1.47	0.72	50.9	77.5	88.7	94.5	97.6	18.7	46.2	58.8	62.9
43	1.47	0.78	46.9	83.3	89.6	92.4	97.1	18.6	45.6	55.9	58.9
44	1.43	0.75	47.6	85.1	90.8	93.3	96.6	13.6	37.2	50.1	54.9
46	1.46	0.77	47.3	83.8	89.5	93.0	97.3	15.4	43.6	53.5	57.5
40	1.45	0.71	51.0	75.1	85.0	91.4	96.9	17.7	43.6	53.3	57.3
Average	1.46	0.75	48.7	81.0	88.7	92.9	97.1	16.8	43.2	54.3	58.3
High-volatile B											
10				Coke too weak to test							
19	1.48	0.74	50.0	26.5	38.9	53.6	67.8	2.4	4.6	11.1	21.6

FIGURE 2—Section of splint coal (x 200).

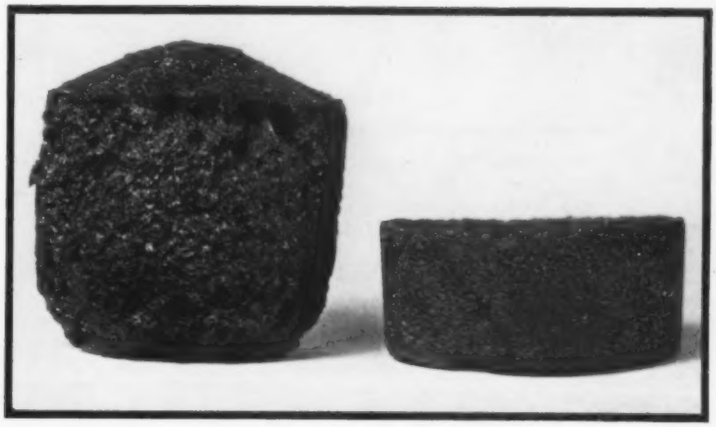


FIGURE 3—Cokes formed from the bright coal (*left*) and the splint coal.

The splint coal gave a considerably higher yield of tar than the bright coal but less coke and gas (Table XII). The volume of the coke from the bright coal was about twice that of the charge, whereas that from the splint was about the same (Figure 3). Comparative work of this sort by the Bureau of Mines has not been extensive enough to permit broad general conclusions as to the effect of type on carbonizing properties of a coal. It is known, however, that splint coals rich in spores (resinous matter), as in the foregoing example, will give high

TABLE V

Physical Properties of Coke, 900 Degrees C. Tests

Coal No.	True specific gravity	Apparent specific gravity	Cells, per cent	Shatter test, cumulative per cent upon				Tumbler test, cumulative per cent upon			
				2-in. screen	1½-in. screen	1-in. screen	¼-in. screen	2-in. screen	1½-in. screen	1-in. screen	¼-in. screen
Low-volatile											
23	1.88	0.94	50.1	33.4	65.3	91.6	98.8	0.0	9.3	55.0	79.9
26	1.87	0.87	53.5	52.5	83.5	96.1	98.8	3.6	31.2	68.4	76.9
48	1.88	0.76	59.6	54.8	84.6	96.5	98.7	6.7	37.2	63.7	70.8
51	1.90	0.90	52.6	56.0	82.3	96.0	98.8	2.9	35.1	67.0	75.3
41	1.86	0.94	49.5	38.4	72.3	94.3	98.7	1.3	26.4	63.1	77.3
Average	1.88	0.88	54.1	47.0	77.6	94.9	98.8	2.9	27.8	63.4	76.0
Medium-volatile											
27	1.85	0.84	54.7	36.6	79.4	96.2	98.8	1.7	26.6	68.0	77.9
5	1.92	0.79	59.0	65.1	85.8	95.7	98.7	7.5	40.3	66.0	73.5
8	1.90	0.80	57.8	59.7	85.3	93.6	95.7	2.8	34.4	62.8	71.8
25	1.92	0.89	53.6	29.9	68.0	92.6	98.5	0.0	15.0	59.4	78.7
55	1.86	0.86	53.8	40.3	79.2	95.5	98.8	2.6	28.6	68.2	76.8
Average	1.89	0.84	55.8	46.3	79.5	94.7	98.1	2.9	29.0	64.9	75.7
High-volatile A											
28	1.86	0.84	54.7	29.6	69.7	93.7	98.1	0.0	12.9	52.9	69.3
43	1.83	0.87	52.5	33.0	64.2	91.1	98.0	0.0	8.9	47.9	67.8
44	1.84	0.84	54.3	35.0	76.6	95.0	98.8	0.0	13.4	51.6	68.6
46	1.87	0.90	51.9	34.8	64.0	91.4	98.1	1.0	13.8	53.4	71.5
40	1.77	0.84	52.5	22.3	70.7	93.8	98.1	0.0	11.2	53.5	73.9
Average	1.83	0.86	53.2	30.9	69.0	93.0	98.2	0.2	12.0	51.9	70.2
High-volatile B											
10	1.97	0.77	60.9	38.6	67.4	83.0	96.8	0.0	6.3	32.9	70.3
19	1.92	0.76	60.4	16.3	43.6	71.0	97.4	0.0	0.0	20.9	78.4
Average	1.95	0.77	60.7	27.5	55.5	77.0	97.1	0.0	3.2	26.9	74.4

TABLE VI

Physical and Chemical Properties of Gas, 500 Degrees C. Tests

Coal No.	Specific gravity	Gross heating value*		Composition, dry, per cent by volume							
		Bu. per cu. ft.	Btu. per lb. of coal	CO_2	Illuminants	O_2	H_2	CO	CH_4	C_2H_6	N_2
Low-volatile											
23	0.528	790	900	4.1	1.7	0.4	30.9	0.9	50.7	9.8	1.5
26	0.564	861	1,080	2.0	1.7	0.6	25.8	1.5	54.1	12.1	2.2
48	0.511	862	950	3.1	1.5	0.3	28.4	1.0	54.7	9.7	1.3
51	0.521	866	1,040	3.2	1.7	0.4	28.2	1.1	55.1	8.9	1.4
41	0.507	862	1,010	1.9	1.4	0.3	29.7	1.5	53.1	10.8	1.3
Average	0.526	848	996	2.9	1.6	0.4	28.6	1.2	53.5	10.3	1.5
Medium-volatile											
27	0.555	894	1,320	1.9	2.5	0.3	26.5	2.1	53.5	12.2	1.0
5	0.595	860	1,040	3.5	2.0	1.2	22.9	2.3	51.8	11.9	4.4
8	0.655	851	1,070	3.2	2.3	2.2	20.4	1.8	48.9	12.5	8.7
25	0.607	883	1,050	5.6	2.2	0.4	23.0	2.5	51.2	13.5	1.6
55	0.521	887	1,060	2.3	1.7	0.3	27.7	1.2	53.3	12.3	1.2
Average	0.585	875	1,180	3.3	2.1	0.9	24.1	2.0	51.7	12.5	3.4
High-volatile A											
28	0.618	945	1,250	4.1	2.2	0.3	19.6	3.2	54.4	15.2	1.0
43	0.607	932	1,190	4.2	2.5	0.2	23.3	2.9	50.7	15.5	0.7
44	0.595	934	1,310	3.7	2.4	0.3	22.1	2.7	54.1	13.7	1.0
46	0.595	911	1,160	4.4	2.3	0.4	23.4	2.9	51.3	13.9	1.4
40	0.614	942	1,200	4.4	2.9	0.4	20.7	2.9	53.0	14.5	1.2
Average	0.606	933	1,222	4.2	2.5	0.3	21.8	2.9	52.7	14.6	1.1
High-volatile B											
10	0.654	806	850	9.0	2.8	1.0	20.3	5.6	46.8	10.5	4.0
19	0.716	866	1,080	9.7	2.7	0.5	16.5	5.6	49.8	13.1	2.1
Average	0.685	836	965	9.4	2.8	0.8	18.4	5.6	48.3	11.8	3.1

*Stripped of light oil and saturated with water vapor at 60 degrees F. and 30 in. of mercury.

TABLE VII

Physical and Chemical Properties of Gas, 900 Degrees C. Tests

Coal No.	Specific gravity	Gross heating value*		Composition, dry, per cent by volume							
		Btu. per cu. ft.	Btu. per lb. of coal	CO_2	Illuminants	O_2	H_2	CO	CH_4	C_2H_6	N_2
Low-volatile											
23	0.272	483	2,620	0.8	1.6	0.4	69.2	3.6	22.7	0.0	1.7
26	0.301	544	2,880	0.8	2.6	0.2	63.7	2.8	28.4	0.8	0.7
48	0.287	520	2,670	0.9	2.1	0.4	65.9	3.2	26.2	0.0	1.3
51	0.296	520	2,630	1.0	2.2	0.3	66.0	3.2	25.9	0.0	1.4
41	0.276	520	2,760	0.4	2.2	0.4	68.3	2.6	24.8	0.2	1.1
Average	0.286	517	2,712	0.8	2.1	0.3	66.6	3.1	25.6	0.2	1.2
Medium-volatile											
27	0.332	569	3,070	0.9	4.2	0.3	59.0	4.0	30.1	0.9	0.6
5	0.368	605	3,090	1.2	3.1	0.9	57.1	4.2	30.6	1.5	3.6
8	0.368	596	2,950	1.6	4.0	0.7	55.5	4.5	32.4	0.3	1.0
25	0.353	571	2,930	1.7	3.3	0.3	58.7	5.4	27.9	1.5	1.2
55	0.292	547	2,900	0.7	3.1	0.3	63.5	3.0	28.0	0.3	1.1
Average	0.343	578	2,988	1.2	3.5	0.5	58.8	4.2	29.8	0.9	1.5
High-volatile A											
28	0.369	615	3,210	1.2	4.2	0.2	54.1	6.4	31.4	1.6	0.9
43	0.376	605	3,310	1.5	5.6	0.3	53.5	6.0	31.0	0.9	1.2
44	0.367	601	3,310	1.3	5.5	0.2	55.1	5.2	31.2	0.8	0.7
46	0.360	599	3,160	1.4	5.2	0.3	56.0	5.5	29.4	0.8	1.4
40	0.397	633	3,430	1.5	6.0	0.5	51.1	6.1	32.7	0.9	1.2
Average	0.374	611	3,284	1.4	5.3	0.3	54.0	5.8	31.1	1.0	1.1
High-volatile B											
10	0.436	535	2,650	4.3	3.8	0.4	53.1	11.3	25.6	0.4	1.1
19	0.475	610	3,260	3.9	5.8	0.3	47.3	10.2	30.6	1.0	0.9
Average	0.456	573	2,955	4.1	4.8	0.4	50.2	10.8	28.1	0.7	1.0

*Stripped of light oil and saturated with water vapor at 60 degrees F. and 30 in. of mercury.

TABLE VIII

Properties of Tars, 500 Degrees C. Tests

Coal No.	Specific gravity 15.6° C. / 15.6° C.	Heating value, Btu. per lb.	Per cent pitch	Distillate, per cent by volume of dry tar			Neutral tar oil, per cent by volume		
				Acids	Bases	Neutral oils	Olefins	Aromatics	Paraffins and naphthenes
Low-volatile									
23	1.07	17,090	51.5	4.6	0.6	43.3	4.8	77.6	17.6
26	1.05	17,200	46.9	7.5	0.9	44.7	4.0	61.4	34.6
48	1.06	17,050	48.6	6.8	0.5	44.2	6.0	78.2	15.8
51	1.05	17,210	48.1	6.2	0.8	45.0	5.8	71.1	23.1
41	1.04	17,320	46.2	5.2	0.7	47.9	7.3	60.5	32.2
Average	1.05	17,174	48.3	6.1	0.7	45.0	5.6	69.8	24.7
Medium-volatile									
27	1.01	17,440	42.3	11.5	0.9	45.3	6.5	48.2	45.3
5	0.99	17,210	15.5	22.6	1.6	60.2	11.0	75.2	13.8
8	1.00	17,280	26.7	19.0	0.3	54.0	12.0	54.2	33.8
25	1.01	16,980	36.2	19.9	1.4	42.5	11.0	53.4	35.6
55	1.03	17,230	47.2	8.5	0.8	43.6	4.5	57.6	37.9
Average	1.01	17,228	33.6	16.3	1.0	49.1	9.0	57.7	33.3
High-volatile A									
28	1.03	16,870	43.5	19.3	1.3	35.9	9.8	54.1	36.1
43	1.00	17,300	41.1	14.7	1.4	42.8	7.8	48.2	44.0
44	1.02	17,160	41.5	15.5	1.2	41.8	8.6	49.8	41.6
46	1.01	17,170	37.1	16.1	1.6	45.2	8.3	50.2	41.5
40	1.00	17,200	41.8	16.5	1.2	40.5	8.6	47.8	43.6
Average	1.01	17,140	41.0	16.4	1.3	41.2	8.6	50.0	41.4
High-volatile B									
10	1.04	16,510	33.8	29.8	0.4	36.1	15.8	53.5	30.7
19	0.99	17,275	36.7	16.6	1.6	45.1	14.3	46.3	39.4
Average	1.02	16,893	35.3	23.2	1.0	40.6	15.1	49.9	35.1

TABLE IX

Properties of Tars, 900 Degrees C. Tests

Coal No.	Specific gravity 15.6° C. / 15.6° C.	Heating value, Btu. per lb.	Per cent pitch	Distillate, per cent by volume of dry tar			Neutral tar oil, per cent by volume		
				Acids	Bases	Neutral oils	Olefins	Aromatics	Paraffins and naphthenes
Low-volatile									
23	1.18	16,380	64.2	3.9	1.0	20.8	9.0	88.8	2.2
26	1.16	16,570	69.6	2.7	0.9	24.2	7.2	81.7	11.1
48	1.20	16,030	71.5	1.0	0.9	18.7	11.0	88.6	0.4
51	1.19	16,260	71.9	1.3	0.6	17.6	9.3	90.2	0.5
41	1.18	16,490	72.5	1.8	0.7	18.7	7.9	88.0	4.1
Average	1.18	16,346	69.9	2.1	0.8	20.0	8.9	87.5	3.7
Medium-volatile									
27	1.18	16,510	70.2	3.0	1.3	20.7	9.3	83.9	6.8
5	1.16	16,345	47.7	9.1	1.6	40.0	18.4	81.2	0.4
8	1.20	16,330	69.9	2.9	0.7	19.4	15.1	83.8	1.1
25	1.11	16,430	45.5	11.5	2.2	39.7	10.5	77.4	12.1
55	1.19	16,350	72.0	2.5	0.6	19.9	8.5	89.4	2.1
Average	1.17	16,393	61.1	5.8	1.3	27.9	12.4	83.1	4.5
High-volatile A									
28	1.15	16,390	55.6	7.7	1.7	32.1	11.3	81.6	7.1
43	1.19	16,290	67.2	3.2	1.7	21.8	9.9	88.5	1.6
44	1.19	16,350	66.9	3.5	1.5	22.2	9.9	88.9	1.2
46	1.19	16,290	65.2	4.4	1.5	22.9	10.6	87.2	2.2
40	1.17	16,320	64.2	4.0	1.6	24.1	11.1	85.3	3.6
Average	1.18	16,328	63.8	4.6	1.6	24.6	10.6	86.3	3.1
High-volatile B									
10	1.17	16,220	55.1	7.5	1.1	29.8	17.3	81.3	1.4
19	1.15	16,265	51.5	6.5	2.9	34.9	15.0	82.3	2.7
Average	1.16	16,243	53.3	7.0	2.0	32.4	16.2	81.8	2.1

yields of tar. Perhaps the most characteristic carbonizing properties of splint coal are failure to swell when coked under no load (*e.g.*, Fischer assay) and production of a weak coke. For example, the shatter 1½ in. and the tumbler 1 in. indices of coke made at 900 degrees C. from High Splint high-volatile A coal were 53.9 and 35.7 per cent, respectively, compared to 69.0 and 51.9 per cent for high-volatile A coals in Table V. However on blending the High Splint coal with 30 per cent of Beckley low-volatile coal a coke was produced at 900 degrees C. having a 1½ in. shatter index of 75.5 per cent and a 1 in. tumbler index of 57.8 per cent.

This coke would be suitable for blast furnace use. It must be concluded, therefore, that splint coal should not be condemned unconditionally for making coke; it may be feasible to produce a really good coke from it by blending with a reasonable amount of another coal.

EFFECT OF CARBONIZING TEMPERATURES

It has been shown that rank and type of a coal affect the yields and qualities of carbonization products obtainable from it. Given a coal suitable in these respects, the next variable to be considered is carbonizing temperature. In the coke and gas industries high temperatures (800 to 1100 degrees C. effective wall temperatures) are the rule, although several plants in

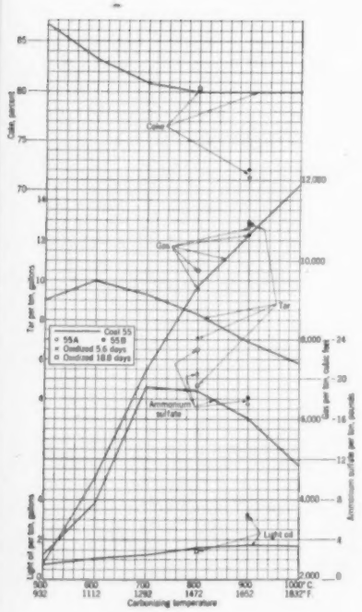


FIGURE 4—Yields from Sewell bed (Wyoming Mine) coal and blends with Alma bed. (Left)

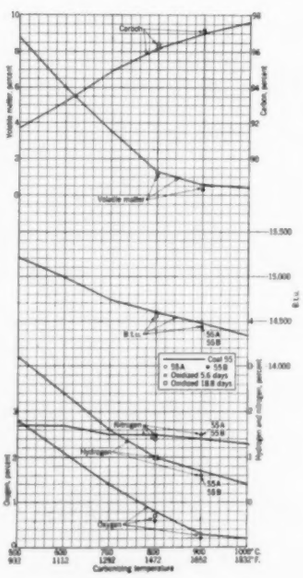


FIGURE 5—Analysis of coke, ash and moisture free, from Sewell bed (Wyoming Mine) coal and blends with Alma bed. (Right)

TABLE X

Composition of Light Oils, 500 Degrees C. Tests

Coal No.	Refined light oil from gas, per cent by volume				Olefins, per cent by volume
	Benzene	Toluene	Paraffins	Solvent naphtha	
Low-volatile					
23	....	....	....	....	....
26	....	....	....	....	....
48	14.8	20.2	41.9	23.1	22.6
51	13.9	21.2	44.9	20.0	23.0
41	13.5	13.4	51.6	21.5	22.1
Average	14.1	18.3	46.1	21.5	22.6
Medium-volatile					
27	....	....	....	....	21.7
5	5.2	5.4	44.9	44.5	....
8	4.1	3.3	35.9	56.7	....
25	9.4	16.4	43.8	30.4	25.5
55	12.1	12.0	56.8	19.1	20.7
Average	7.7	9.3	45.4	37.7	22.6
High-volatile A					
28	9.7	8.1	65.2	17.0	25.1
43	8.7	8.5	61.7	21.1	29.4
44	9.2	8.8	58.9	23.1	29.7
46	8.2	9.0	63.3	19.5	25.6
40	10.4	8.3	62.4	18.9	28.9
Average	9.2	8.5	62.3	19.9	27.7
High-volatile B					
10	10.3	6.8	47.3	35.6	19.4
19	7.0	9.1	53.1	30.8	38.4
Average	8.7	8.0	50.2	33.2	28.9

TABLE XI

Composition of Light Oils, 900 Degrees C. Tests

Coal No.	Refined light oil from gas, per cent by volume				Olefins, per cent by volume
	Benzene	Toluene	Paraffins	Solvent naphtha	
Low-volatile					
23	55.4	27.2	3.2	14.2	10.0
26	39.7	30.0	4.1	26.2	12.9
48	59.2	26.6	0.9	13.3	10.8
51	61.3	24.7	1.9	12.1	12.0
41	51.1	27.1	3.2	18.6	13.3
Average	53.3	27.1	2.7	16.9	11.8
Medium-volatile					
27	55.0	24.7	2.9	17.4	11.8
5	31.7	22.5	4.5	41.3	....
8	49.1	16.9	0.8	33.2	....
25	42.4	24.9	12.2	20.5	16.1
55	56.6	25.7	3.3	14.4	9.9
Average	47.0	22.9	4.7	25.4	12.6
High-volatile A					
28	61.6	20.4	7.5	10.5	11.3
43	72.0	19.5	2.2	6.3	9.2
44	67.9	21.5	2.2	8.4	10.7
46	65.4	21.2	3.6	9.8	10.2
40	63.9	19.4	6.2	10.5	11.0
Average	66.2	20.4	4.3	9.1	10.5
High-volatile B					
10	66.0	21.6	2.6	9.8	4.0
19	65.2	23.1	3.3	8.4	14.7
Average	65.6	22.4	3.0	9.1	9.4

Europe and one in this country are making domestic coke at around 650 degrees C. Figures 4 to 10, inclusive, show the effect of carbonizing temperature in the BM-AGA retorts for Sewell bed medium-volatile coal on the yields and quality of carbonization products obtained. The figures also show the effect of blending the Sewell coal with Pittsburgh bed high-volatile A coal by tests at 900 degrees C. and that of controlled pre-oxidation of Sewell coal by tests at 800 degrees C.

Figure 4 shows the variation in yields of coke, gas, tar, light oil, and ammonium sulphate with carbonizing temperature for Sewell bed coal. The yield of gas increases almost linearly from 2375 to about 11,900 cu. ft. per ton of coal as the carbonizing temperature is raised from 500 to 1000 degrees C. The yield of tar increases from 9 to 10 gallons per ton between 500 and 600 degrees C. and then gradually decreases to 5.8 gallons at 1000 degrees C. The yield of coke decreases from 86.6 per cent at 500 degrees C. to 80.0 per cent at 800 degrees C. and remains virtually the same at 900 and 1000 degrees C. The yield of light oil increases from 0.8 gallons per ton at 500 degrees C. to 1.7 gallons at 900 degrees C. and does not change appreciably when the temperature is raised to 1000 degrees C. Ammonium

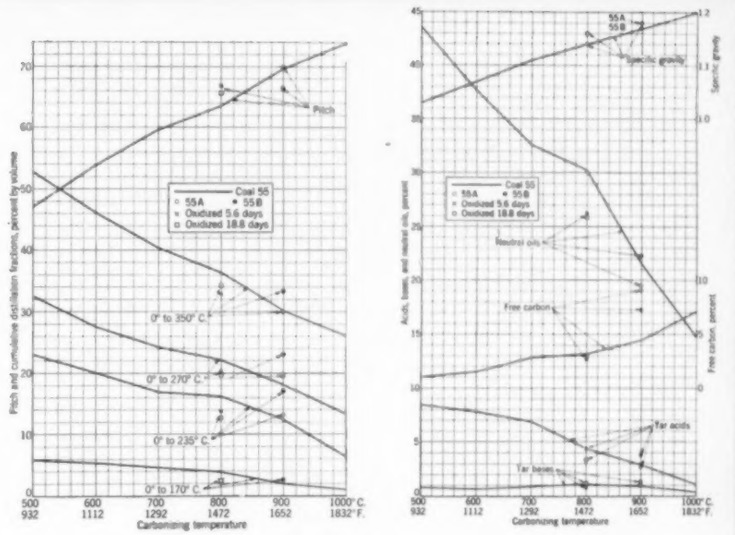


FIGURE 9—Distillation of tar from Sewell bed (Wyoming Mine) coal and blends with Alma bed. (Left)

FIGURE 10—Composition of tar from Sewell bed (Wyoming Mine) coal and blends with Alma bed. (Right)

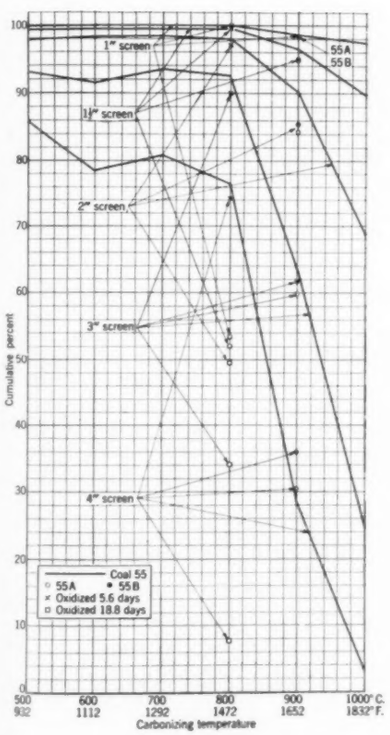


FIGURE 6—Screen analysis of coke from Sewell bed (Wyoming Mine) coal and blends with Alma bed.

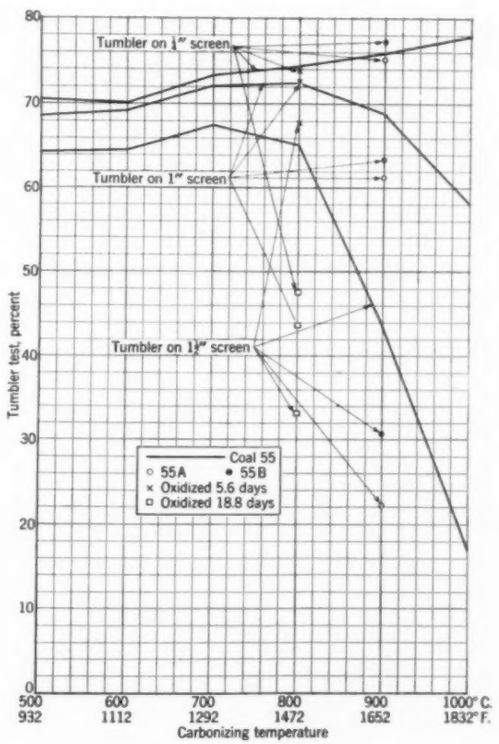


FIGURE 7—Tumbler tests of coke from Sewell bed (Wyoming Mine) coal and blends with Alma bed.

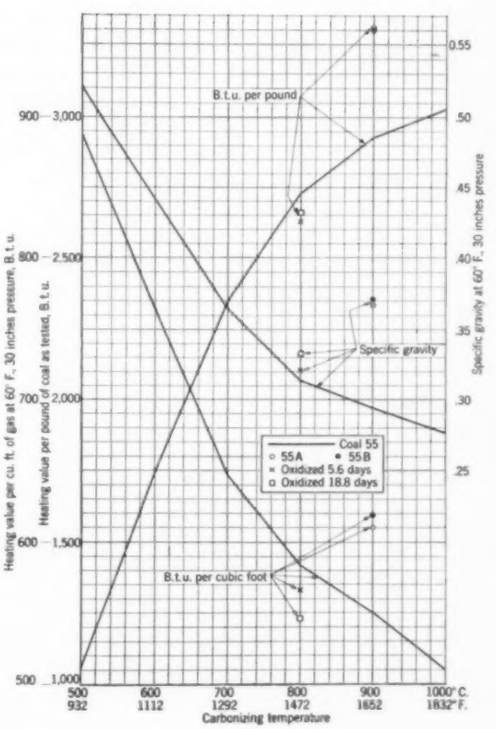

B.t.u. per pound
Specific gravity
B.t.u. per cubic foot
Heating value per cu. ft. of gas at 60° F., 30 inches pressure, B.t.u.
Heating value per pound of coal as tested, B.t.u.
Specific gravity at 60° F., 30 inches pressure
Coal 55
55A
55B
Oxidized 5.6 days
Oxidized 18.8 days
Carbonizing temperature

FIGURE 8—Physical constants of gas from Sewell bed (Wyoming Mine) coal and blends with Alma bed.

TABLE XII

Analyses of Layer Samples of Pond Creek Coal and Yields of Carbonization Products by the Fischer Assay

Analyses, as-received basis

Layer	Proximate, per cent			Ultimate, per cent						Heating value, Btu. per lb.	Softening temperature of ash, degrees F.
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur		
3 (splint)	1.4	36.4	58.0	4.2	5.3	82.7	1.2	6.0	0.6	14,760	2,910
4 (bright)	1.7	34.7	60.9	2.7	5.5	82.6	1.6	6.8	0.8	14,700	2,630

Assay yields

Layer	Yields, per cent by weight of coal								Yield per ton of coal	
	Volatile sulphur	CO_2	H_2S	Coke	Tar	Light oil	Gas	Water	Tar, gallons	Gas, cu. ft.
3 (splint)	0.13	0.42	0.14	74.0	16.5	1.07	4.7	3.6	39.6	1,780
4 (bright)	0.17	0.35	0.18	76.1	13.2	0.73	5.1	4.7	31.8	2,130

sulphate increases rapidly to 19.2 pounds per ton at 700 degrees, remains virtually the same at 800 degrees C. and then decreased to 11.4 pounds at 1000 degrees C.

For the same carbonizing time the yield of tar at 500 degrees C. would be somewhat higher than at 600 degrees C., but at this end of the temperature range the carbonizing time is excessively long (32 hours compared to 22 at 600 degrees C.) and accordingly the tar vapors have a longer time of exposure to retort temperatures. Both time and temperature of exposure of the tar vapors affect their decomposition and in this case it appears that the effect of time was the more pronounced.

Blending with 80 (55A) and 70 per cent (55B) of Alma bed, high-volatile A coal decreases the yields of coke, and increases the yields of tar, light oil, and ammonia but has little effect on the volume of gas produced. The rank of the blends is lower than that of coal 55, and these results are to be expected. Preoxidation of coal 55 for 5.6 and 18.8 days in air at 99.3 degrees C. has little effect on the yields of coke and light oil but increases the yield of gas slightly and that of ammonia considerably. The yield of tar is decreased from 8.3 gallons per ton to 7.1 by oxidation for 5.6 days, and further oxidation (total 18.8 days) reduces it to 4.7 gallons.

Figure 5 shows the variation of the main chemical constituents and heating value of the coke with carbonizing temperature. The total carbon increases almost regularly, and the hydrogen, oxygen, and heating value decrease about proportionately. The nitrogen decreases more slowly and the volatile matter decreases sharply to the 800 degree C. carbonization temperature and then decreases more slowly as the carbonizing temperature is raised. In other words, the tendency of high carbonizing temperatures is to reduce the coke to carbon and ash; however, it is difficult, if not impossible, to remove the last traces of nitrogen and hydrogen by heating.

Figure 6 shows the screen analysis of the dry, quenched coke after careful removal from the BM-AGA retorts to avoid breakage. The largest coke is produced in the 500 degree C. tests; from 800 to 1000 degrees C. the size decreases rapidly because of the formation of shrinkage cracks. The blend cokes are smaller than those from 100 per cent Sewell coal. In general, blends of this kind, in which a large percentage of high-volatile coal is used, produce smaller coke than the higher rank coal (*e.g.*, Sewell) alone. Preoxidation of Sewell coal reduces the size of the coke made from it.

Figure 7 gives the results of tumbler tests of the cokes plotted against the carbonizing temperature. Cumulative percentage remaining on the 1 in. sieve is taken as the "stability factor" of the coke and that remaining on the ¼ in. sieve as the "hardness factor."[5] The higher the carbonizing temperature the harder and less abradable the coke becomes; however, the maximum stability is attained in the coke made at 800 degrees C. Higher temperatures cause shrinkage cracks to develop which decrease stability. The coke from the blend containing 70 per cent of Pittsburgh bed coal (55B) is slightly harder but less stable than that from the 100 per cent charge of Sewell bed coal.

Figure 8 shows the heating value per cubic foot and per pound of coal carbonized and specific gravity of the gases plotted against the carbonizing temperature. From the gas maker's point of view the most significant graph is the Btu. per lb. of coal, or the yield of gas on the heating-value basis. The yield on this basis increases almost linearly with the carbonizing temperature; and accordingly, other things being equal, the gas maker will carbonize at the highest temperature his retorts will stand. However, the chart shows that the heating value of the gas per cubic foot decreases with increasing carbonizing temperature, and it must not fall below the legal minimum for distribution which usually is about 520 Btu. per cu. ft. Furthermore, it has been shown that high carbonizing temperatures lower the quality of the coke; gas-works coke must be good enough for the domestic coke market. Actually the gas maker usually carbonizes high-volatile A coals at high temperatures, obtaining a high yield of gas rich enough for distribution

and coke that is satisfactory for domestic heating but unsatisfactory for metallurgical use.

Figure 9 shows the results of fractionation tests on the tars plotted against the carbonizing temperature. It is clear that the percentage of volatile constituents decreases regularly as the carbonizing temperature is raised, and that of pitch increases proportionately. The volatile constituents are cracked on being exposed to high temperatures, and the products are pitch, light oil, and gas. Some free carbon is also formed, particularly if the temperature is high. The yield of tar from this coal at 500 degrees C. was 9 gallons per ton compared to 5.8 gallons at 1000 degrees C., but the former contained 47.2 per cent of pitch compared to 73.9 for the latter. Calculating the yield of pitch on the basis of gallons per ton of coal ($9 \times .472 = 4.25$ gallons; $5.8 \times .739 = 4.29$ gallons) shows that it does not change much with carbonizing temperature. However, it is known that pitch does decompose rapidly on heating, so the inference is that in this instance it was formed as rapidly as it decomposed.

Figure 10 shows the variation in specific gravity and chemical composition of the tar with carbonizing temperature. The specific gravity increases regularly as the temperature is raised, and the free carbon content of the tar also increases; the neutral oils and tar acids decrease, and the tar bases remain virtually constant.

EFFECT OF PREOXIDATION OF COAL

It is well-known that bituminous coking coals of high oxygen content (more than 10 per cent) do not produce coke of the best quality and that weathering, such as takes place in open storage, slowly increases the oxygen content of a coal. Weathering may improve the coking power of some high-volatile A coals, but with low- and medium-volatile coals the coking power begins to decrease even with slight weathering or oxidation. Some high-volatile A coals become too fluid in the plastic state to produce good cokes; the coke lacks density and has large cells. Limited oxidation decreases the fluidity[6] of the coal while it is plastic and so improves the coke made from such coals.

In the survey of carbonizing properties of American coals, the Bureau of Mines uses an accelerated weathering test to determine the effect of preoxidation on the yields and quality of carbonization products obtained from each coal tested. The apparatus is shown in Figure 11. It comprises a steam-jacketed rotating steel drum that is half-filled with a charge of 400 pounds of coal. Air is passed through the drum at a constant rate and the temperature of the coal is kept at 99.3 degrees C. The volume of the air is determined by a gas meter, and a composite sample of the exit gases is taken for analysis, so that the oxygen used per unit weight of coal and the products formed can be determined. The process is interrupted periodically, and 4 lb. samples are removed for small-scale carbonization tests. When the small-scale tests begin to indicate a change in the trend of carbonizing properties with oxidation, a sample of approximately 180 lb. of coal is removed from the drum and tested in the BM-AGA 18 in. retort. A test on this scale yields coke having properties that compare favorably with those of industrial cokes. Furthermore, enough coke and by-products are obtained for complete chemical and physical examination and direct comparison of these data can be made with corresponding data obtained from fresh coal under the same carbonizing conditions. Oxidation of the coal remaining in the drum is continued until the coking power appears to be virtually destroyed, and a second large-scale test is made.

Table XIII gives the results of preoxidation tests for a representative high-volatile A coal and for a representative low-volatile coal.[7]

For both coals the yields of tar decrease and those of liquor and ammonia increase in a regular manner as the amount of oxygen consumed increases. Yields of coke and gas increase with oxygen consumed for the high-volatile coal but decrease for the low-volatile coal. Oxidation increases the apparent specific gravity of cokes from both coals. The coking properties of the high-volatile coal are improved slightly with oxidation up to 1.0 per cent oxygen consumed, whereas the coke from the low-volatile coal is noticeably inferior to that

FIGURE 11—View of apparatus for controlled oxidation of coal.

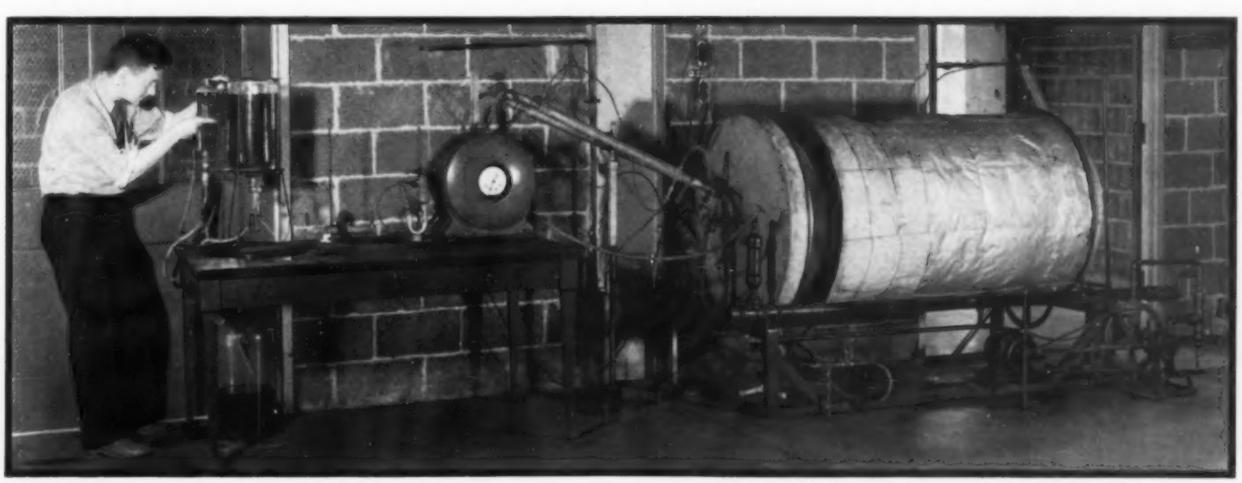


TABLE XIII

Effect of Oxidation of Coal on Yields of Carbonization Products and on Properties of Coke

Oxygen used, per cent of dry coal	Time at 99.3°C., days	Carbonization yields,* per cent**						Physical properties of coke**					
		Coke	Tar	Gas	Liquor	Light oil	Total ammonia	Amount fused, per cent	Apparent specific gravity	Stability	Hardness	Friability	Shatter index
Pittsburgh bed high-volatile A coal													
0	0	65.1	9.7	16.2	4.9	1.0	0.285	97.4	0.83	33.8	61.8	68.7	76.6
0	0	1	1	1	1	1	1	1	1	1	1	1	1
0.5	1.5	1.009	0.938	1.006	1.041	1	1.025	1.002	1	0.997	1.002	0.990	1.023
1.0	3.7	1.017	0.866	1.012	1.061	1	1.053	1.003	1	0.994	1.003	0.990	1.031
2.0	8.7	1.029	0.732	1.031	1.122	1	1.168	1.004	1	0.959	0.971	1.044	1.014
3.0	14.5	1.037	0.598	1.049	1.204	1	.....	1.002	1	0.763	0.647	1.128	0.953
Pocahontas No. 4 low-volatile coal													
0	0	84.6	2.0	11.3	1.3	0.5	0.278	98.0	0.85	61.3	63.7	47.5	95.5
0	0	1	1	1	1	1	1	1	1	1	1	1	1
0.5	1.9	0.998	0.900	1	1.308	1	1.004	0.918	1.024	0.873	0.879	1	0.965
1.0	4.5	0.994	0.800	1	1.692	1	1.007	0.699	1.035	0.742	0.754	1.257	0.892
1.5	7.5	0.996	0.750	0.991	2.000	.80	1.011	0.301	.....	.....	.....	1.589	0.790

*Basis, moisture- and ash-free coal.
**All values for oxidized coals expressed as ratios to values for fresh coal.

from the fresh coal when only 0.5 per cent oxygen has been consumed. It will be observed that Pittsburgh coal requires four times as much oxygen consumed (2.0 per cent/0.5 per cent) as Pocahontas to reduce the hardness of the coke by approximately the same percentage of that for the fresh coal.

Fortunately low- and medium-volatile coals usually consume oxygen much more slowly than coking coals of lower rank; otherwise it would not be practical for the coke-plant operator to store them as in present pract ce. The Pocahontas No. 4 sample tested oxidized faster than is normal for coals of this rank,[7] probably because it contained some cannel coal.

EXPANDING PROPERTIES OF COKING COALS

A coal may be suitable in all other respects for manufacture of metallurgical coke but expand so much during coking that it would ruin coke ovens if charged into them without admixture of a contracting coal. Low-volatile coals are highly expanding and medium-volatile coals usually are moderately to highly expanding. High-volatile A coals are virtually always contracting, although expansion has been reported for some coals of this rank under certain carbonizing conditions. However, the relationship between volatile content and expanding properties is far from linear; it often happens that two coals of the same volatile content differ widely in expanding properties. Accordingly it is necessary for the coke-oven operator to test each new coal before charging it into his ovens or before using it in mixtures. The Bureau of Mines uses the oven shown in Figure 12 for determining the expanding (or contracting) properties of coals. It is a vertical-slot-type oven heated electrically from both sides in a manner similar to a coke oven and is charged from a coal lorry shown at the top. It is provided with a movable wall that can be fixed relative to the back wall or allowed to move laterally under known loads. The usual procedure in testing is to apply a constant load of 2.2 lb. per sq. in. and to measure the lateral displacement as carbonization of the charge progresses. With the most highly expanding coals the movable wall may be displaced 35 per cent of the thickness of the charge when this method of testing is used; contracting coals may shrink as much as 20 per cent under the same conditions. It usually is considered that if a coal does not expand more than 2 per cent in this test it is safe to charge it in a coke oven. However, with such "borderline" coals care must be taken that the density of the charge is not too high and that the rate of coking is moderate. Usually the average density of the charge in a coke oven is around 50 lb. per cu. ft., but because of non-uniformity in charging it may be considerably higher locally. The expanding properties of a coal vary approximately lineally with the density of the charge, and if the density of the charge of a "borderline" coal is high in any part of the oven this fact may change it from a safe coal to one that will ruin the oven walls in time. One should avoid rapid coking with "borderline" coals; however, expansion is affected much more by rapid heating with some coals than with others. An extremely dry coal will expand more than one that is moderately moist, mainly because the density of the charge varies with the moisture content of the coal. This property of the coal often can be turned to account; that is, if an operator finds he is having trouble with a dry "borderline" coal it often happens that he can obviate the difficulty by adding some moisture before charging it into the ovens.

PLASTICITY OF COAL AND MECHANISM OF COKE FORMATION

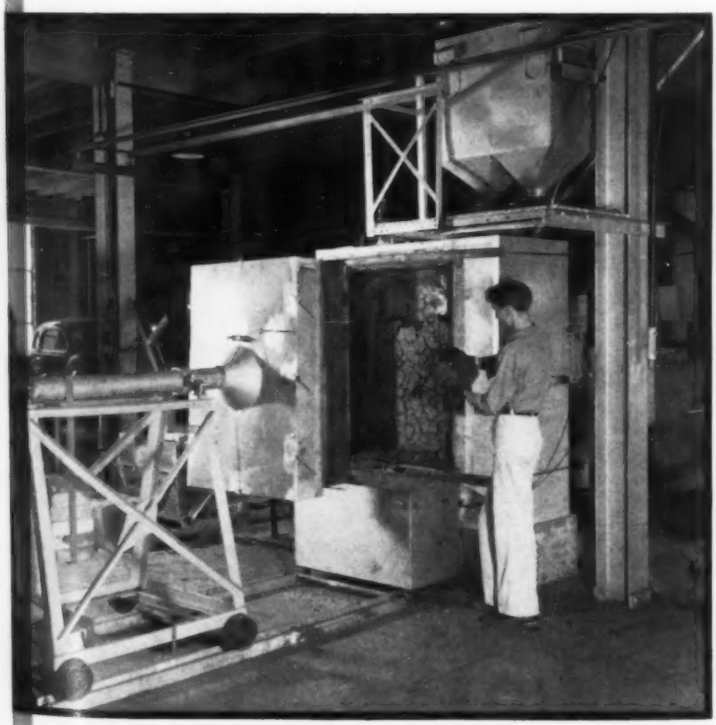
The quality of the coke produced from a coal is determined largely when it is in the semi-fused or plastic state. That is, during the coking process and in the range of temperature of approximately 390 to 490 degrees C. the fusible constituents melt and incorporate those that are infusible, forming a mass similar to paste paint in consistency. It differs from paint, however, in that as soon as it forms it begins to decompose, giving off gases and tar vapors. As the temperature is raised decomposition becomes more rapid until finally all the fusible matter is decomposed and the residue is low temperature coke. During carbonization in a coke oven two thin layers of plastic coal pass through the charge in planes parallel to the heating walls and meet in the middle of the oven at the end of the coking period. The gases and vapors given off in the layers distend the plastic mass more or less, depending on its viscosity, leading to formation of voids similar to those in rising dough. The voids become cells in the finished coke. The plastic properties of coals tested by the Bureau of Mines have been measured by methods that have been described elsewhere.[8]

The writer proposes to classify coals used for coke making in respect to plastic properties as "fluid" and "viscous." Work done in the Bureau of Mines laboratory shows that the viscosity of coal in the plastic state tends to increase as the rank of the coal increases.[9] High-volatile A coals are in the highly fluid class and low-volatile coals in the highly viscous class. The relationship between fluidity and rank is not linear because properties other than rank affect the fluidity of a coal. The type of the coal is an example; splint coal has different plastic properties from bright coal of the same rank.[10] However, coals used industrially for coke making usually are predominantly of the bright type, so that the relationship between rank and plastic properties holds to a close approximation. The ranges of rank covered by fluid and viscous coals and their carbonizing properties may be summarized as follows:

A—*Fluid coals: high-volatile A and some medium-volatile coals.* These coals are highly expanding when coked under no load; but when coked under load and at constant volume, as in a coke oven, they actually shrink because the highly fluid, plastic mass offers little resistance to escape of the large volume of gases and tar vapors generated therein. The coke is characterized by large cells, relatively low apparent specific gravity, and low resistance to shatter and abrasion. With high rates of coking it usually is fingery and cross-fractured. Preoxidation reduces the fluidity[6] of such coals, and limited preoxidation tends to improve the quality of the coke. Fluid coals consume oxygen rapidly, but the amount of oxygen required to destroy the coking power completely is considerably greater than for viscous coals.[7] Blending coals of this class with viscous coals reduces the fluidity and improves the coking power approximately in proportion to the amount of low-volatile coal used.

B—*Viscous coals: low-volatile and some medium-volatile coals.* Coals in this class do not expand excessively when coked under no load. However, when coked in a coke oven at constant volume considerable expansion force is exerted laterally by the plastic coal because of the high resistance offered by the viscous mass to escape of gases and tar vapors therefrom. Virtually all dangerously expanding coals are in the viscous class. The coke produced from them is characterized by small cells, high apparent specific gravity, and high resistance to shatter and abrasion. It also is blocky. When exposed to weather these coals consume oxygen slowly, but a relatively small amount of oxygen consumed will destroy their coking power.

FIGURE 12—View of Bureau of Mines oven for determining expansion of coal.



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DISCUSSION

PRESENTED BY

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A. R. POWELL, *Chief Chemical Engineer*, Engineering and Construction Division, Koppers Company, Pittsburgh, Pennsylvania.

R. W. CAMPBELL, *Superintendent*, By-Product Coke Plant, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

F. W. WAGNER, *Chief Chemist*, By-Product Department, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

C. P. BETZ: I have enjoyed Mr. Davis' paper very much and while listening to it I was attempting to tie up the results he obtained with some we got in Detroit during the past year while experimenting with several grades of high-volatile coals. What was of uppermost importance to us was to find a blend of coals which would produce a metallurgical coke conducive to good blast furnace operation and at the same time produce the desired yield of valuable by-products which we could recover.

One of the first mixes used consisted of a southern coal blended with Pocahontas. The former was very desirable from a chemical standpoint and the resultant coke was very low in ash and sulphur. The physical properties of the coke, however, were poor. The cell structure was open with thin, weak, cell walls and the stability factor was low. Although the volatile matter in the coal mix was approximately 32 per cent the yield of by-products was poor, noticeably the cu. ft. of gas per ton of coal. In order to check our gas figures, we had two meters of different makes in the gas line. The yield of tar and light oils was also very discouraging.

We next tried a mix consisting of two Pittsburgh seam coals with 25 per cent Pocahontas which resulted in a marked improvement in coke structure and blast furnace practice. The tar, gas and light oil yields also showed an increase.

Ten per cent of a medium volatile West Virginia coal was then introduced in the mix and the desired toughening of the coke was accomplished with satisfactory blast furnace results and by-product yields.

Oven tests on several other blends were run and chemical and physical examinations made of the cokes but due to the fact that no more than six ovens of any one blend were charged, we were unable to segregate the gas and therefore unable to get any data pertaining to by-product yields.

I think it would be of interest and value if some of the blends used in our tests could be coked in the experimental plant mentioned in the paper, to determine how close experimental data checks with operating results.

A. R. POWELL: We have followed with much interest during the past ten years the survey of coking coals that has been carried on by Mr. Davis and others in the Bureau of Mines. The present paper of Mr. Davis gives some of the more important conclusions, especially as regards the yield of coke and by-products from several types of coal and at different carbonizing temperatures.

The apparatus and method of procedure used in this test provide, without very much doubt, an excellent basis for comparison, between different coals, of their characteristic behavior on coking and the relative yield of by-products from each.

However, when it comes to predicting the actual quality of coke and the actual quality and yields of by-products that can be expected from the use of a given coal or coal blend in commercial coke ovens constructed of silica brick, considerable caution must be used in translating the test results into expected plant performance. This is probably more especially true of the physical quality of the coke, since the shape and size of the carbonizing chamber, the rate of carbonization, pressure on the coal, and several other factors that are different between the test apparatus and commercial ovens affect the physical properties of the coke considerably.

It must be realized, however, that the Bureau of Mines-American Gas Association carbonization test procedure has furnished us with a valuable and highly successful tool for studying the effect of the many variables involved in coal carbonization. A comprehensive investigation such as we see summarized in Mr. Davis' paper would have been impossible without this equipment.

On several occasions we have used the data from the Bureau of Mines carbonization survey in helping us to predict what changes might be expected in quality or yields of by-products by changing certain operating conditions at the ovens. There is no question but that trends in quality and yields may be predicted by use of these data, and even an approximate figure for the quantitative result may often be deduced.

The by-product coke industry should be and is, I feel sure, grateful to Mr. Davis and his colleagues for this painstaking study that has been carried on for so many years.

R. W. CAMPBELL: The humus constituents of certain coals are increased by oxidation, which seems to show that the action of the absorbed oxygen is to attack the resin compounds. As we know that carbon dioxide and moisture form the chief products of the earlier stages of heating masses of coal, it seems probable that the result is a conversion of the resinic into humus

bodies with the evolution of these gases. It is this change that leads to serious deterioration in the gas, tar and coke made from coal which has been stored too long.

However, it must not be assumed that slight oxidation or heat effects are always injurious as certain high volatile coals such as Vesta No. 4 and No. 5, produce a stronger, blockier coke after having been slightly weathered. It is my opinion that the proportion of resinic and humus constituents in these coals is not present in the proper amounts, and that the binding material or resinic material is in excess of that required for producing good coke. Large amounts of resinic or cementing substances in a coal are apt to evolve large quantities of gases while they are in a plastic state, causing the resultant coke to be light and porous. If the excess resinic material in the Vesta coals is converted into humus material without too great a reduction in the resinic content, the proportions of resinic and humus materials are so altered that a much improved coke is produced.

Weathering of coals also results in the oxidation of a certain proportion of the pyritic sulphur to ferrous sulphate which is leached out by rainfall, thereby reducing the total sulphur content of the coal. Shale and bony material is also oxidized to the point where they are soft and crush very easily, thereby eliminating some of the cross-fracture in the resulting coke.

The following tabulation is a comparison of cokes produced from freshly mined Vesta No. 4 coal with that produced from Vesta No. 4 coal which had been stored for four and one-half years.

	Raw Vesta No. 4	*Raw Vesta No. 4 stored for 4½ years*
PROXIMATE ANALYSIS		
Per cent volatile matter	34.39	34.54
Per cent fixed carbon	55.89	56.81
Per cent ash	9.72	8.65
Per cent sulphur	1.20	1.02
COKE PHYSICAL TESTS		
Screen— Per cent on 4 in.	5.8	13.9
Per cent on 3 in.	17.7	23.4
Per cent on 2 in.	33.0	33.2
Per cent total on 2 in.	56.5	70.5
Shatter— Per cent on 2 in.	30.8	41.8
Tumbler—Per cent on 1 in.	17.1	21.1
Per cent on ¼ in.	45.4	36.1
Apparent specific gravity	1.003	.935
True specific gravity	1.862	1.812
Porosity	44.49	48.93
Physical fuel value	26.17	31.91

The physical tests shown for Vesta No. 4 coal which had been stored for 4½ years compares with a mixture of 95 per cent freshly mined Vesta No. 4 and 5 per cent of Pennsylvania low volatile coal.

F. W. WAGNER: I think one of the most confusing things about stocked coal and perhaps the reason why some people have been disillusioned about the coking properties of stocked coal (and I am thinking particularly of the Pittsburgh high-volatile coals) is that so frequently they are dealing with a combustion condition of stocked coal. Coal that has been over-oxidized to a point of combustion makes a very, very poor coke. That happens very frequently when coking stocked coal and I think it is the reason why people have formed an opinion that stocked coal makes an inferior coke. Mild oxidation improves the coking properties of Pittsburgh high-volatile coals.

Deppeler DISCUSSION

(Continued from page 46)

the effect of arc voltage. Further comments on the effect of arc voltage on penetration would therefore be interesting.

J. H. DEPPELER: Mr. Persons, in his remarks, says that he believes that there is a tendency on the part of many engineers to try to seize upon one general type of electrode as an answer to all of their problems. He says that he is confident that there is no such electrode and in this, I heartily agree.

Mr. Turnock, in his remarks, has questioned my statements on the cause of "fish-eyes" but I agree with his statement also, which is that "fish-eyes" in a dirty deposit may be caused by sonims in the steel, which would cause places of high stress concentration. The remarks in my paper were directed to X-ray clean deposits, wherein "fish-eyes" will definitely occur due to a difference in grain size. I still believe that without preheating, a layer of deposited metal should be restricted to ⅛ in. because, at normal temperatures, the heat effect of a succeeding layer will be limited to about ⅛ in. With preheating, this penetration will be deeper. With the hand-cold technique, or cooling to some temperature below the room, then ⅛ in. may be too thick. The proper thickness of a layer, to produce no "fish-eyes" in the tensile specimen, would be an amount which would show no difference in grain structure except in the cover bead on a nick-break test. With such a clean nick-break test, "fish-eyes" will not occur in the tensile specimen except where sonims may be present. Stress-relief alone may not recrystallize the structure, so that, with coarse crystal laminations, "fish-eyes" may still occur after stress-relief, but if the heat be elevated so as to intentionally grain-refine the structure, these "fish-eyes" will then disappear.

I am in hearty accord with Mr. Westendarp's statements and know that the concentricity of the all-position electrodes, with their relatively light coatings, is much more important than with the heavy-coated, flat welding electrodes. Electrode manufacturers attempt to keep this concentricity as perfect as possible.

I believe also that someone, some day, will come out with a straight polarity, all-position electrode. This will probably be of the all-mineral coated type, but whether it will ever be equal to the high cellulose type electrode, with its reversed polarity, is still a question.

Mr. Westendarp questions my statements on the penetration of bare wire welding and probably this is from an electrical standpoint, but the fact remains that where high carbon steel is to be welded, as, for instance, in the case of half-soling of rails, the bare wire deposit, although completely lacking in ductility, does work better and makes lower carbon deposits because of lack of pick-up. Probably the factors which govern this are not electrical but are entirely a question of the rate of cooling of the deposit, and bare wire, regardless of its arc voltage, will solidify instantly with the high carbon steel, whereas a coated electrode deposit remains molten for a brief instant, but at least long enough to allow the high carbon to migrate.

MODERNIZATION of Existing OPEN HEARTH Equipment

By GEORGE L. DANFORTH, JR., *President*

OPEN HEARTH COMBUSTION CO.

CHICAGO, ILLINOIS

▲ IT has been the writer's observation that the open hearth facilities of this country average a higher degree of modernity than such facilities in any of the other major steel producing countries, but nevertheless, a large proportion of our open hearth capacity consists of furnaces and equipment which cannot compete economically with the furnace designs and auxiliary equipment now available and largely installed in the more modern plants. Such uneconomical furnaces and equipment should be modernized to that determinable extent wherein the expenditure required for the work will be fully justified by the economies which should be accomplished.

No steel producing works can operate successfully without an ingot supply of good quality produced at a competitive cost. The question of when and how to best modernize existing open hearth furnaces and auxiliary equipment is therefore one of major importance to the steel industry. It presents a complex problem which involves many factors requiring careful consideration, such as the superior designs and equipment now available, present condition of existing units, the increased production and operating economies possible to obtain with modernization, the quality of the steel products, the amount of expenditure required, and the extent to which the expenditure will be justified by the improved overall results which may be reasonably expected. These numerous factors often require more consideration and balancing to find the correct answer than are required in the engineering and building of a new shop, in which it is not necessary to abandon any items of some value in order to use modern units.

GEORGE L. DANFORTH, JR.

The numerous features now available for consideration and possible use in the work of modernizing any open hearth plant vary greatly in the amount of expenditure required for their installation, the value of the operating improvements accomplished thereby, and in the amount of expenditure relative to the amount of savings. These features may be listed and commented upon as follows:

A—Modern design of ports, checkerwork, roofs, doors and frames, and insulation require little or no additional construction cost when applied to the existing furnace at any time it is rebuilt, and in some cases when the furnace requires a ground level rebuilding, the slag pocket construction can be improved. Such improvements can often be used to increase the furnace efficiency in production, quality, and cost of operation by from five to fifteen per cent, depending on the obsolescence of the construction displaced. Such features will give the greatest overall improvement relative to their cost of installation.

B—The installation of sloping back walls, furnace combustion controls, straight line flues and valves, modern designed molds, larger charging boxes and similar improvements will afford a handsome return on the

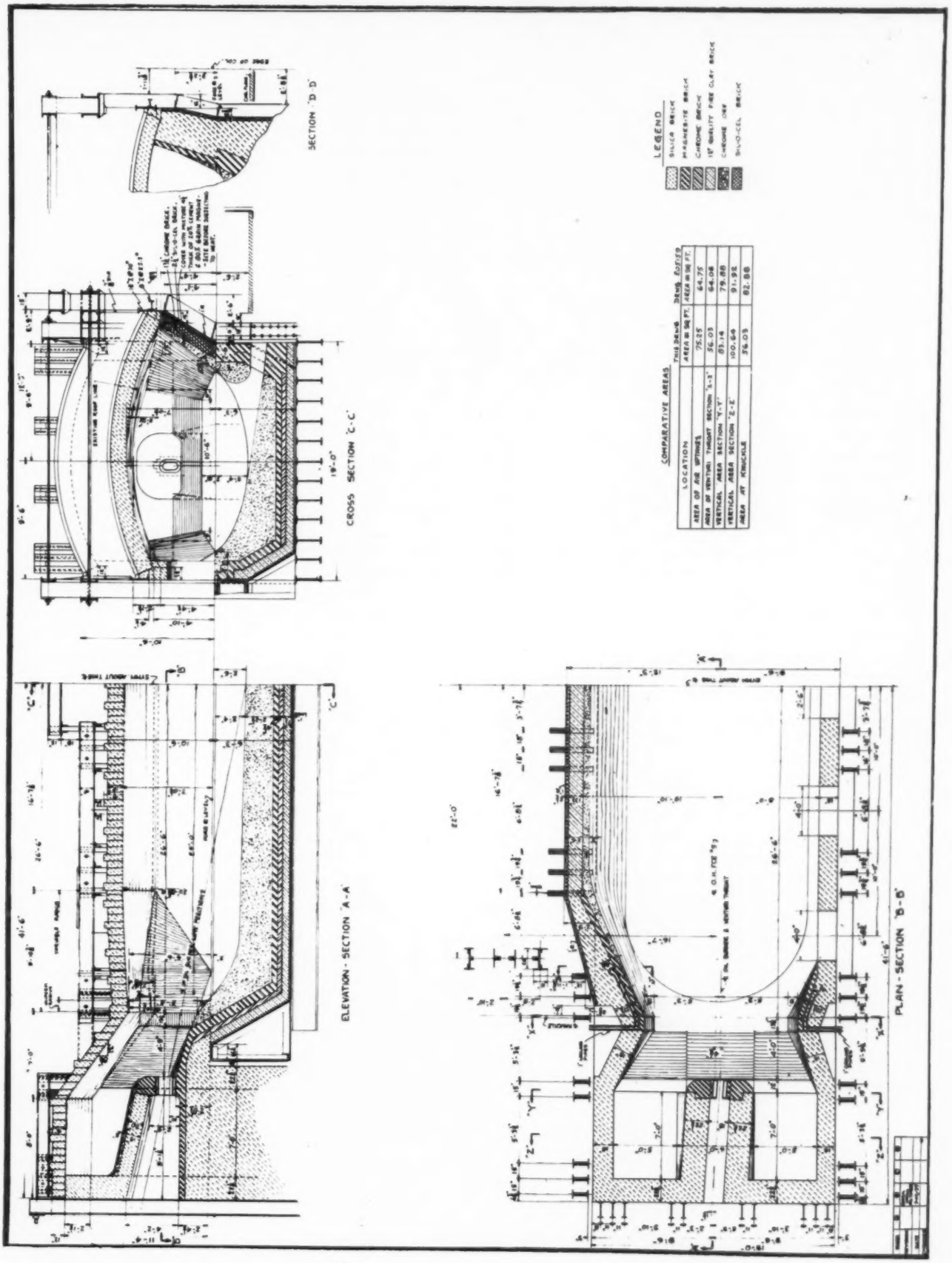


FIGURE 1—General arrangement of modern oil fired open hearth furnace, with venturi port and sloping backwall.

moderate expenditures which can be made from time to time to provide such facilities. Furthermore, when major repairs are made to auxiliary equipment such as charging machines, cranes, and stock and ingot buggies, more modern parts can be used at a moderate cost in excess of what it would otherwise cost to restore the equipment to its original design.

C—Major expenditures are required to materially enlarge the size of the open hearth furnace for tapping larger heats and to provide the equipment for handling such heats; or to install such auxiliary equipment as waste heat boilers, mold preparing facilities and the like. The amount of such expenditure will of course vary in accordance with the degree to which the furnaces and supporting equipment are enlarged. However, as a guide, it may be stated that to enlarge a 100-ton furnace and its casting equipment to tap and handle 150-ton heats, an average expenditure of about $225,000 per furnace is required. In estimating the overall returns from such an expenditure, the additional capacity, as well as the savings in operating expense and quality of production should be given due consideration.

Having now in mind the features available for modernization purposes, with a general appraisal of their relative value and cost of installation, it is well to survey the status of the existing open hearth furnaces and their auxiliary equipment, in order to determine how and to what extent the features available can be provided with an investment which will be justified by the improved results which can be expected.

For this survey, the existing open hearth plants may be grouped and discussed as quite modern, semi-modern, semi-obsolete, and quite obsolete. In this grouping it should be understood that a number of plants have some furnaces and equipment which have been modernized to some extent, and that such plants should be considered as being in more than one of the groups mentioned.

The quite modern group comprises most of the open hearth plants built within the past eight years with furnaces casting an average of about 175 tons per heat. Such plants are equipped with most, but not all, of the modern facilities now available. With minor expenditures for the lacking facilities, such plants can increase their efficiency to a worthwhile extent, and produce with the lowest operating cost now possible.

The semi-modern group is composed largely of those plants built some fifteen years ago, and those plants of earlier vintage which have done some modernizing work since first built. These plants generally cast heats of from 100 to 125 tons, and produce with an operating cost averaging fifteen to twenty per cent in excess of the quite modern group. In such plants the furnaces can be rebuilt with more modern construction to tap somewhat larger heats, the auxiliary equipment can be improved and strengthened to handle the larger units, and additional equipment installed where now lacking. This will result in a material increase in production and an operating cost within five to ten per cent of the quite modern group.

The semi-obsolete group may comprise those plants built some twenty years ago which have done no modernizing work worthwhile, and those plants built in earlier years and later improved to some extent. The furnaces in this group may vary in size of heat tapped from 60 to over 100 tons. In some cases it may be found possible and desirable to modernize the semi-obsolete plant to the same degree that the semi-modern plants can be modernized, but in most such plants it will be found more economical to limit the enlargement of the furnaces to about a fifty per cent increase, with auxiliary equipment strengthened and improved in accordance therewith, and to be content with an operating cost which should be no more than fifteen to twenty per cent in excess of the quite modern group.

The quite obsolete group generally comprises those ancient plants still producing small heats with the equipment originally installed and with a very high operating expense. Even in this group there are some plants which can be modernized to an extent whereby the resulting overall improvement in production, operating expense and in quality of products will justify the expenditure required for the modernization. However, in the quite obsolete group there are plants which should be abandoned, for the degree of modernization which could be accomplished would not result in overall savings sufficient to warrant the large amount of expenditure required.

For the purpose of this paper, the open hearth plant may be considered in four divisions; namely, furnaces, stocking and charging facilities, casting and stripping facilities, and miscellaneous equipment.

The open hearth furnace is a metallurgical machine comprising many parts between its roof and stack. For each of such parts there are now available modern designs and equipment which have demonstrated their individual values. To whatever extent the existing furnace is deficient in the use of such modern parts, its efficiency is subject to improvement, and wherever and whenever it can be determined that the results will warrant the investment, the modern part or parts should be installed.

The larger furnaces casting larger heats are inherently more efficient in operating expense than smaller units, but this advantage may not be the controlling factor in determining the best manner in which to modernize the particular open hearth plant under consideration. If larger heats are to be made, then to the cost of enlarging the furnace units must be added the cost of increasing the capacity of ladles, ladle cranes, and strengthening the building and crane runways to accommodate the heavier loads. If the combined cost is calculated to be justified by the increased efficiency that will result, then the furnaces should be enlarged to whatever extent is warranted. Otherwise, the furnaces may be modernized without the thought of casting larger heats. It should be kept in mind, however, that with an enlarged furnace the original sized heat can be produced in less time and the furnace production increased accordingly, and that the full capacity of the furnace can be utilized at some later time when it is found necessary or desirable to provide the handling facilities for larger heats.

In some shops where the furnaces can be readily enlarged but the ladles and cranes for large heats cannot be provided except with an unreasonable expenditure, it may be desirable to enlarge the furnaces to cast larger heats with the use of a bifurcated spout to cast into two ladles. However, this is a compromise arrangement which has its disadvantages, and should be used only when existing conditions are quite unusual. Again it

can be kept in mind that large ladles and ladle cranes with the necessary building reinforcement may be installed at some later time to cast single heats corresponding in weight to the full capacity of the enlarged furnaces. The merit of such a procedure might be termed doubtful, but a step in the right direction.

Figure 1 shows the No. 5 furnace at the Indiana Harbor plant of the Youngstown Sheet and Tube Company as rebuilt and put into operation in February, 1937. In this rebuilding, the installation cost of the modernizing features—venturi port, sloping back wall, and special checkerwork—was less than $10,000 above the usual rebuilding cost. The improvements installed have resulted in an additional production of more than 1,000 tons per month, with over ten per cent reduction in fuel, and a longer furnace life. In the first campaign after being rebuilt, the furnace made 470 heats of 145 tons for a total production of 68,142 tons, with some roof repairs, largely due to a shutdown necessitated by labor conditions. On its last campaign it made 424 heats of 162.4 tons for a total production of 68,871 tons, with no roof repairs whatsoever. During no campaign has it been necessary to clean slag pockets or checkerwork, and in all campaigns the life of the end and front walls has been better than normal. All furnaces in this plant now use venturi ports; and sloping back walls, special checkerwork and minor improvements are being installed as rebuilding conditions permit. This illustrates the major results which may be accomplished with relatively small expenditure.

The Ford Motor Company had ten furnaces, five stationary and five tilters, in its open hearth plant, casting heats of 110 net tons. About two and a half years ago, these furnaces and the auxiliary equipment were in good average condition, and could almost be classified as semi-modern. Nevertheless, as an increase in total steel producing capacity was desired, the management wisely decided it was better to modernize the existing furnaces and auxiliary equipment rather than to gain the desired capacity by installing additional furnaces and equipment. To date, six of the furnaces, four stationary and two tilters, have been modernized to cast heats of 180 net tons. Figure 2 shows one of the modernized furnaces, all of which are equipped with venturi ports, special checkerwork and tapered doorways, the four stationary furnaces being also equipped with full sloping back walls. With all six furnaces the original regenerators, valves and stacks were retained, and with the stationary furnaces, the hearth and port end foundations were utilized. The production of the six enlarged furnaces is now equal to that of nine furnaces as originally built, and the fuel consumption has been materially reduced. The Ford program requires a major expenditure, which is more than warranted by the gain in producing capacity and efficient operation.

The stocking and charging facilities of the open hearth department should be so arranged and adequate that the furnaces can be charged without delays and the stocking and charging operation accomplished at the minimum cost. The proper charging of the furnace should be the major consideration, for no matter how efficient the furnace may be, it cannot produce satisfactorily in respect to tonnage, costs or quality when subjected to charging delays.

Considerable thought has been given to the possibility of improving the charging operation by using methods and means radically different from those now employed, whereby the furnace charge might be quickly completed in one operation through a so-called open front furnace, or through the top by removing or opening the furnace roof. Either of such methods would require a vast change in the stock handling and charging facilities, and would necessitate radical alterations in the furnace construction and method of maintenance. The main basis for considering such means is the thought that a material increase in production and saving in fuel would be accomplished by rapid charging and completion in one operation.

It has been the writer's experience that little or nothing is gained by completing the average charge in

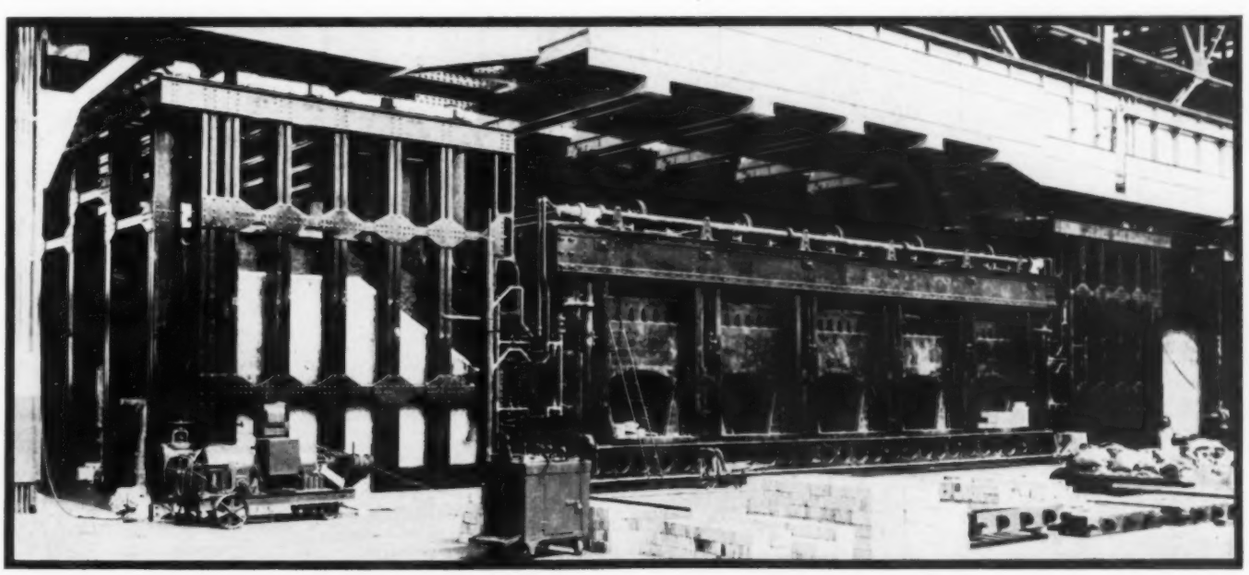


FIGURE 2—View of modernized furnace which was enlarged to 180 tons capacity, and equipped with venturi ports, special checker work, and tapered doorways.

one operation, for in such a case the bottom portion of the charge must be heated through the top portion. Where the charge is made in two or three parts with from thirty to sixty minutes between charging operations, each part is exposed to the furnace flame and heated to a helpful extent before being covered by the next part, and between charges the slag line repairs may be completed. If the volume of the cold charge is much less than average, on account of using a high percentage of hot metal or heavy stock such as bloom butts, then the charge can be completed in one short operation with conventional equipment. If the volume is equal to or more than the average charge, due to using a small percentage of hot metal or to the voluminous nature of the scrap used, then the capacity of the furnace melting chamber is not sufficient to take the entire charge in one operation, and possibly not in two. The essential point is to start the charging operation as soon as possible after the furnace has been tapped, and then to supply the remaining parts of the charge when and as required by the furnace operation.

It is the writer's opinion that whatever small advantage might be obtained by charging through an open front or movable roof would be more than lost in the required construction and maintenance of the furnace, and that the charging operation can best be improved by correcting the deficiencies of the facilities now employed. This can be done as follows:

A—Provide proper arrangement of existing trackage, with additional tracks and cross-overs where needed, so there will be the minimum interference in the movement of stock buggies to and fro between stock piles and furnaces. Storage tracks for charges prepared before required by the furnaces should also be provided.

B—Provide adequate facilities such as magnet cranes and grab buckets or overhead bins to load stock into an adequate equipment of charging boxes as fast as the maximum amount of stock is required at the furnaces. The storage tracks mentioned in (*A*) will reduce the peak requirement.

C—Prepare scrap so that a reasonable weight can be loaded into each charging box. A large amount of bulky scrap may warrant the installation of a scrap compressor either at the source of such scrap or adjacent to the open hearth stock yard. Ordinary mill scrap should be sheared properly for loading into open hearth charging boxes. Scrap produced at the skull cracker or yard shears should be loaded directly into charging boxes.

D—Provide an adequate number of charging boxes, buggies, and charging machines, and keep all in good working condition.

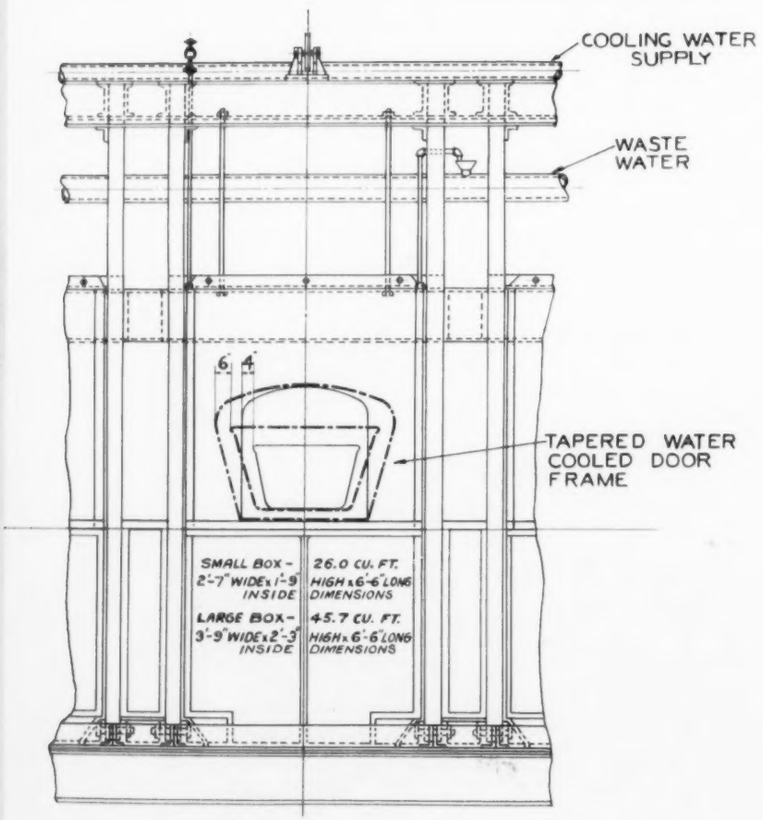
E—Use larger charging boxes and tapered doorways to speed up the loading and charging operations.

The entire stocking and charging division can be simplified in the total amount of equipment required and improved in its cost and quality of operation and service to the furnaces by the use of larger charging boxes and tapered furnace doorways. With the average sized box and the light scrap now used, it is seldom that one-half the charging machine's "strength" capacity is used, while on the other hand, its "movement" capacity is much overtaxed. It frequently happens that light scrap is piled on top of the charging boxes so that a fair weight of scrap will be delivered by each buggy. The charging machine must then toss the scrap from box to box, and greatly delays the charging operation. This delay happens also with heavy mill scrap if even one piece extends sideways above the box and is held in position by the weight of other scrap in the box.

The tapered doorways may be noted in Figure 2, showing the remodeled furnaces of the Ford Motor Company. Their use alone will improve the furnace conditions and charging operation, but a greater advantage will result from the combination of tapered doorway and larger charging box, as shown in Figure 3.

In the majority of existing furnaces, the brick jambs between charging doorways are too wide and the end doorways too far distant from the hearth ends for proper distribution of the furnace charge, and for the inspection and maintenance of the furnace ports and hearth. Wider doorways would correct these conditions, but their use has been limited by their disadvantages when manual work is performed or when the doorways are banked against the hot metal charge or foaming slag before the charge is melted to a safe condition below the sill plate level. The tapered doorway is of normal width at the sill plate, to meet the requirements of the manual labor and banking, and wider at the top to facilitate the charging operation.

FIGURE 3—Tapered doorways improve furnace operation, facilitate charging, and permit the use of larger charging boxes.


COOLING WATER SUPPLY
WASTE WATER
6'4"
TAPERED WATER COOLED DOOR FRAME
SMALL BOX - 2'-7" WIDE x 1'-9" INSIDE
26.0 CU. FT. HIGH x 6'-6" LONG DIMENSIONS
LARGE BOX - 3'-9" WIDE x 2'-3" INSIDE
45.7 CU. FT. HIGH x 6'-6" LONG DIMENSIONS

In concluding the discussion of existing stocking and charging facilities for the cold materials of the furnace burden, it may be said that too often they are much below par, but can be made satisfactory with reasonable judgment and expenditures, and without employing radical or unproved means.

The equipment for storing, mixing and delivering hot metal to the open hearth furnaces should be such that no delay is incurred in emptying and returning the blast furnace ladles or in supplying the open hearth furnaces with a hot metal charge of uniform analysis at the time when the cold charge has been heated and partially melted. If the liquid charge is not uniform in analysis or is made either sooner or later than the proper time, the furnace operation will suffer. Large blast furnace ladles of the closed type are sometimes used in lieu of a storage mixer at the open hearth plant, but such equipment is a poor substitute, as it provides only a limited storage capacity and no mixing capacity for averaging the analyses of successive blast furnace casts. A storage and mixing unit should therefore be installed at the open hearth plant.

When the hot metal requirements of the open hearth plant warrant the use of more than 600 tons of mixer capacity, it is generally desirable to have two units rather than to have the greater capacity in one unit. The transfer equipment between the mixer and furnaces may employ overhead cranes and ladles only, or a transfer car in addition thereto. In either case, it is desirable to use units of as large capacity as the other conditions will permit, so that the number of ladle trips to the furnace will be as few as possible, thus avoiding excessive interference of this operation with that of charging the cold materials.

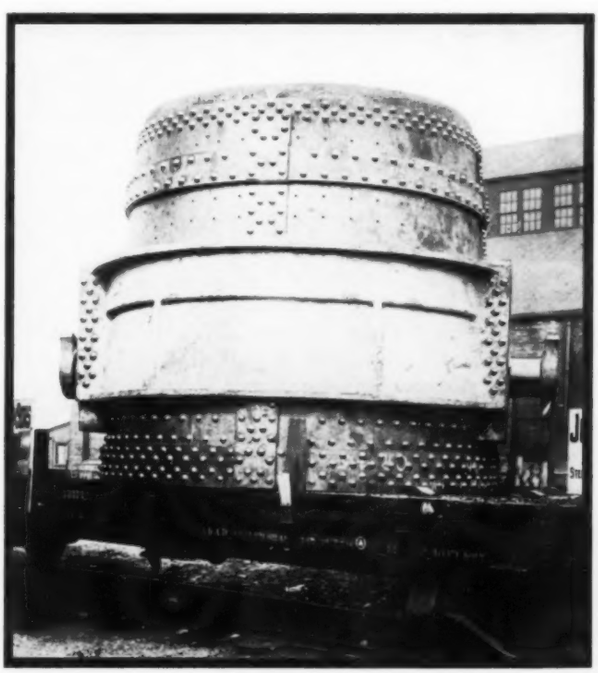
Adequate casting and stripping facilities are necessary for good open hearth operation. Too many well made heats have met with some form of harm or disaster in their journey from the furnace to the soaking pits or scrap yard. Such facilities include working space, pouring cranes, ladles, slag pots, pouring platforms, ingot molds and buggies, mold preparation, strippers, motive power, and a well arranged trackage system. When planning the modernization of these facilities, the following thoughts may be useful:

A—The working space available may be made more ample for either existing or greater production by improving the items of equipment and by a better general arrangement of such equipment, in which there will occur the least interference between the numerous operating movements. It is sometimes possible to increase the working space by extending the casting aisle at one or both ends of the shop, or by removing certain minor operations to other locations.

B—Existing pouring cranes can often be moderately strengthened at a reasonable cost to handle a somewhat greater load, while the dead weight in the load can be decreased by replacing the old riveted ladles by those of welded construction weighing materially less per ton of holding capacity. The weight of heat tapped may then be increased to the extent that the crane capacity is increased and ladle weight is decreased.

Figure 4 illustrates the two types of ladles. In a shop where the weight of the heat cast was increased by twenty tons, the ladle weight was decreased by 11,000

FIGURE 4—A comparison of the modern welded ladle construction with the older riveted construction shows that the former offers reduced dead weight, and may thus permit the handling of larger heats.



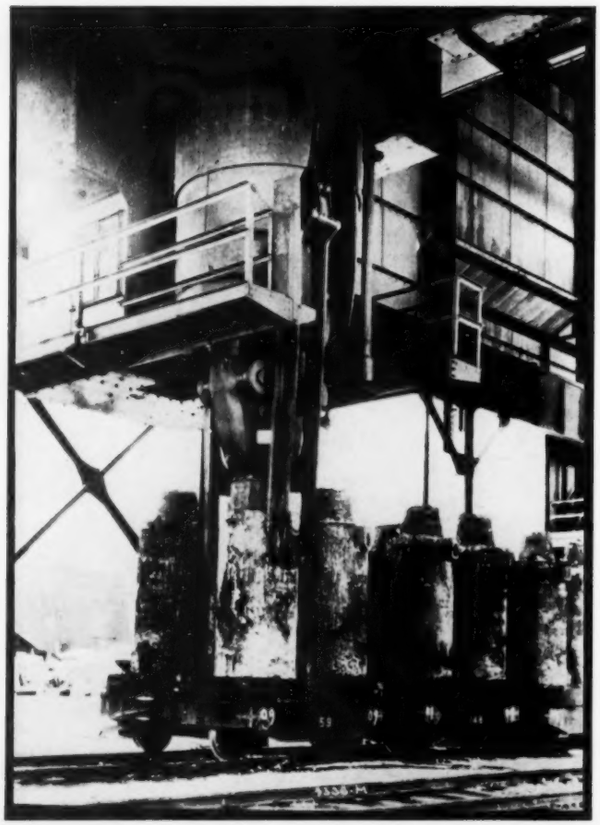
pounds by replacing the old circular riveted ladles with ladles of the oval shaped welded type.

C—When it is desired to install new pouring cranes of much greater load capacity on runways and building structure subject to a limited amount of reinforcement, the wheel base of the crane can be made unusually long to spread the load. In one case this was carried to a point of giving a 226-ton crane a wheel base spread of 68 feet, compared to a bridge span of 35 feet. This installation was made for casting a single 150-ton heat instead of three 50-ton heats from existing tilting furnaces located in a building structure which could not be rebuilt or reinforced to the extent which would have otherwise been required.

D—It is generally considered preferable to use ingot buggies carrying a single row of molds rather than a double row. However, the double row permits the use of a lesser number of buggies and shorter pouring platforms, and requires less space in the stripper, soaking pit and mold preparation buildings.

E—Present day specifications require the making of inverted ingots, generally hot-topped, as well as ordinary small-end-up ingots. All ingots require mold preparation and facilities for this work should be installed to the extent required. It is also necessary to have stripping equipment which will properly handle the several types of ingots mentioned with the least delay between or during such operations. Figure 5 shows a double row of inverted hot-topped ingots being stripped, while Figure 6 illustrates a stripper unit which will strip small-end-up ingots or extract inverted hot-topped ingots without interruption by simply reversing the screw motion, and which with the aid of a stripping yoke, also shown in Figure 6, will extract inverted ingots when not hot-topped.

FIGURE 5—View of overhead stripper crane stripping a double row of inverted hot-topped ingots.



In the general arrangement of an open hearth shop, all of the necessary facilities should be provided and so arranged that all the operations can be performed in correct sequence with no unnecessary backtracking or interference with one another.

Miscellaneous equipment may include fuel making and handling facilities, combustion controls, operating means for furnace doors and valves, and waste heat boilers. Each of the included items has its influence on the efficiency of the plant operation. The fuel facilities should be designed to keep the fuel supply under the control, in respect to quantity, quality, and pressure, which will meet the furnace requirements, which vary considerably from time to time. The combustion controls tie in closely with the fuel facilities, and to a large degree the controls should be automatic, but subject to manual adjustment, so that the man directing the furnace operation can from time to time alter the combustion to meet the furnace requirements and then have the desired combustion automatically maintained. The automatic furnace pressure control is of the greatest benefit relative to its cost of installation, but further controls are desirable and should be given due consideration. Figure 7 shows the control instrument board of a large furnace equipped with controls for measuring the amount of fuel, steam and air used and the temperature of the regenerator flues; and for automatically maintaining the desired furnace pressure, fuel and air ratio, and the roof temperature. Figure 8 shows in diagrammatic form a general arrangement of combustion control for open hearth furnaces fired with a mixture of gas and liquid fuels.

In many plants subject to modernization, rather obsolete means such as compressed air or hydraulic water are used to operate the furnace doors and reversing valves. In some cases two or more units employing such means are used when one motivating unit with a simple mechanical arrangement would reverse all the reversing valves in a predetermined sequence and lapse of time. The excess cost of operating and maintaining such obsolete equipment is a considerable item, and warrants consideration for its elimination.

The operation of a waste heat boiler in connection with an open hearth furnace affords a major saving in the cost of furnace fuel. The boiler operation does not harm, but rather tends to be helpful to the furnace operation. The cost of providing the waste heat boiler is substantially the same per capacity as a fuel fired installation, for while the boiler itself is comparatively more expensive, there are no buildings or fuel handling equipment to provide. The value of the steam produced with a well designed waste heat boiler installation, after deducting the cost of the boiler operation, will amount to an average of thirty per cent of the total cost of the fuel fired in the open hearth furnace. This saving will vary in keeping with the price of fuel in the several steel producing districts, but even in a district favored with

a low priced fuel, the savings will be more than are required to justify the usual cost of making the boiler installation.

It may be said that waste heat boilers are highly desirable when the installation can be made with a normal expenditure in those districts having an average or greater fuel price; less desirable if the cost of installation would be above normal, or in a district favored with a low priced fuel; and not desirable if the expenditure would be above normal and in connection with a low priced fuel.

In a recent installation in the open hearth plant of the Ford Motor Company, each horizontal boiler is twelve feet in diameter and takes the waste gases of one open hearth furnace and one slab heating furnace, developing from 30,000 to 40,000 pounds of steam per hour at a pressure of one hundred and eighty pounds with one hundred degrees of superheat.

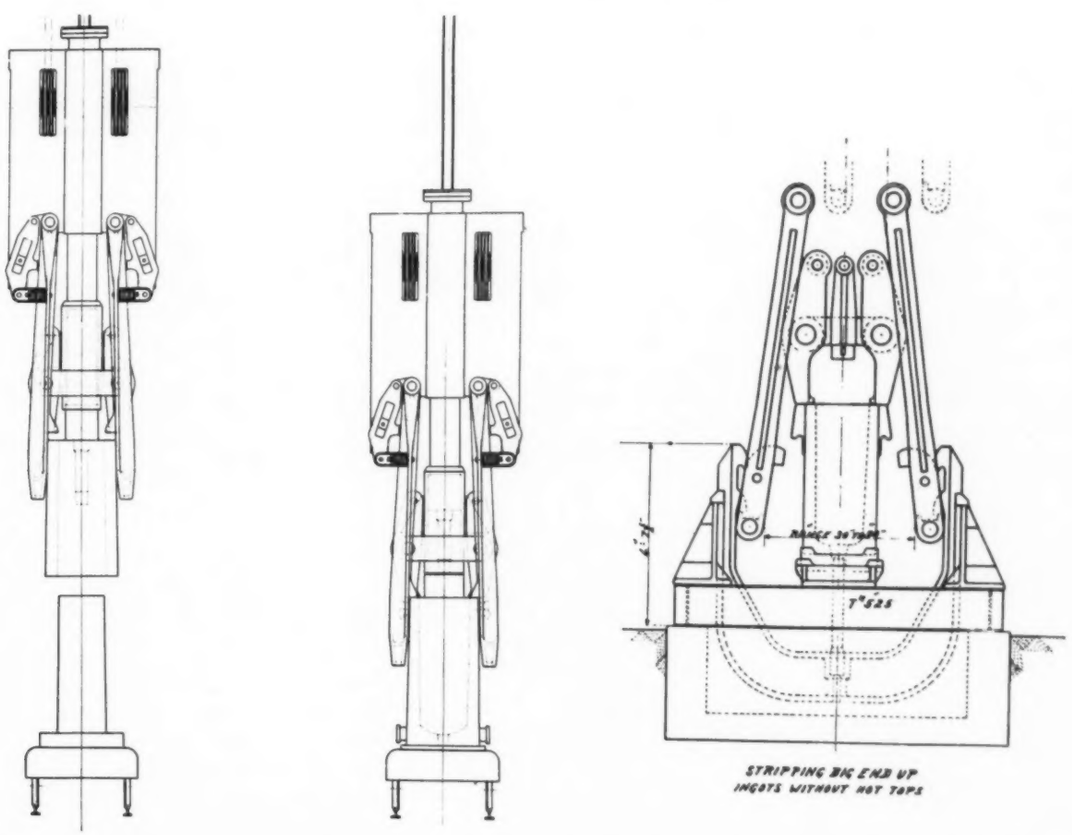
The expenditure required for modernizing work must be justified by improved results expressed in cents saved per year per dollar invested. In making the necessary calculations, the following points may be helpful in determining the correct balance:

With present prices of labor and materials, the cost of building a completely new and modern shop should approximate ten dollars per gross ton of its yearly producing capacity, or ten per cent more or less, depending on the kind of fuel used, cost of clearing site, and other local conditions. With interest and amortization charges fixed at ten per cent per year on an investment of ten dollars, the fixed charge is equal to a cost of one dollar per ton of the full capacity, or one dollar and a half per ton produced if due to fluctuating business conditions, the average production is two-thirds of the full capacity.

In comparison with a new modern plant, the excess operating cost per gross ton will be about seventy-five cents in the semi-modern group, one dollar and a half in the semi-obsolete group, and two dollars and twenty-five cents in the quite obsolete group.

If a plant requiring no additional production, or any portion of such plant, were modernized at an expense of three and a third dollars per annual ton affected, solely to obtain an estimated saving of fifty cents per ton in operating expense, the result would be not more than an even break between the savings and the fixed charge, for ten per cent on three and a third dollars is thirty-three and a third cents, which spread over a production of two-thirds full capacity, equals fifty cents per ton produced. However, the fixed charge would be somewhat reduced if the modernized capacity could be kept in operation above the two-thirds average by shutting down less efficient units when production requirements were subnormal. Furthermore, an expenditure of three

FIGURE 6—Diagram of stripper unit which will strip small-end-up ingots or extract big-end-up ingots.



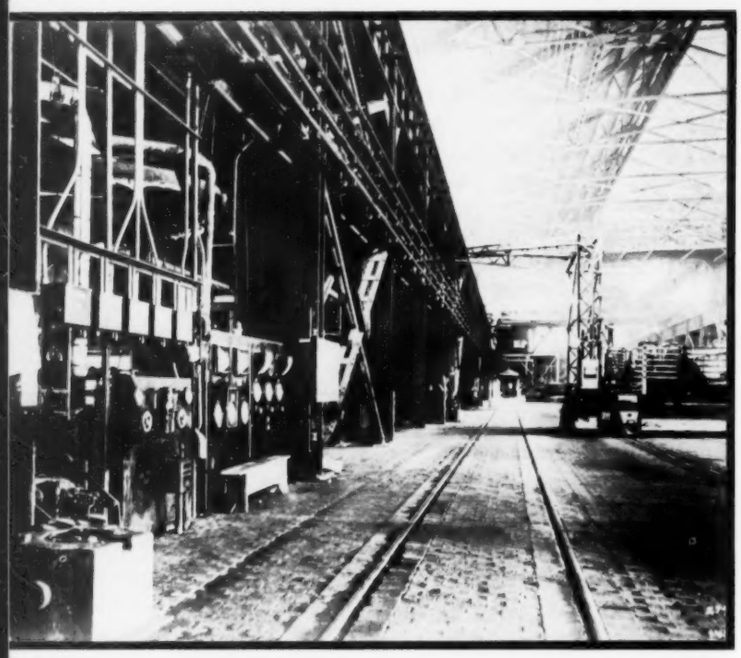


FIGURE 7—Automatic control, subject to manual adjustment, is desirable and should be given due consideration.

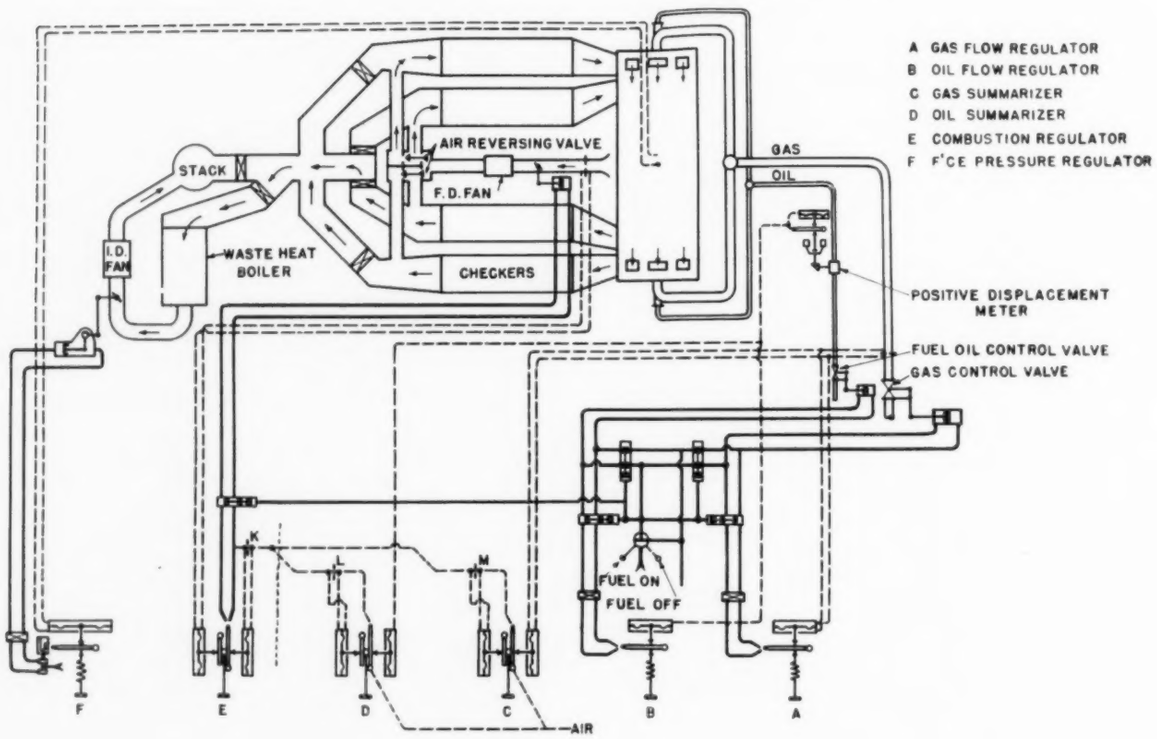
and a third dollars per ton is much more than is generally required to effect a saving of fifty cents, and is here used only to mark the approximate line between unwarranted and warranted expenditures.

When an increase in total producing capacity is required and a saving in operating expense is desired, both to be provided by the modernization work under consideration, than a sum equal to ten dollars per ton of additional capacity may be deducted from the total expenditure, and the balance of the expenditure figured against the savings which will result.

In most plants subject to modernization it will be found that if the work is well planned, the increased production will justify the entire expenditure, and that the savings are a complete gain, or if expressed in reverse order, the amount of expenditure justified by the savings will leave a balance of expenditure which, divided by the additional capacity, will amount to much less than the ten dollars per ton required for a new open hearth plant.

In conclusion, it may be repeated that the modernization of open hearth furnaces and auxiliary equipment is of much importance to the ever expanding steel industry requiring more production, lower costs and better quality; and stated that every plant should have on hand and execute a well planned program of modernization, for it will pay dividends in production, quality and cost.

FIGURE 8—Diagrammatic layout of combustion control for open hearth furnaces fired with a mixture of gaseous and liquid fuels.



DISCUSSION

PRESENTED BY

W. C. KITTO, *Superintendent*, Open Hearth Department, Pittsburgh Steel Company, Monessen, Pennsylvania.

L. F. REINARTZ, *Manager*, Middletown Division, American Rolling Mill Company, Middletown, Ohio.

W. C. KITTO: The management of the Pittsburgh Steel Company agrees heartily with Mr. Danforth that it pays to modernize an old plant. The open hearth furnaces and open hearth department of that company were modernized during a period of slack operation, when it was very difficult to finance such operations, and therefore the work was done an item at a time, but we have finally progressed to the point where results are being obtained from the expenditure.

Bath areas of the furnaces were increased from 550 to 615 sq. ft., and the depth of bath was increased from 28 to 35 in. at the tap hole. A new design of furnace bottom was incorporated, together with basic front walls, sloping back walls, bulkheads, and monkey walls. Archless type door frames were used, with a 9 in. longer door, which permits faster charging and the charging of larger pieces, cutting down the cost of preparation of scrap and the scrap charging time. They have also lengthened the life of front walls, from less than 100 heats to an average of 170.

The furnaces have been modernized to such an extent that production has been increased from a 93 ton heat, averaging 5500 tons per month per furnace, to a 135 ton heat, averaging 9000 tons per month per furnace.

Checker chambers have been insulated, and coolers placed in the division walls of the regenerators. Water-cooled slide valves were installed, giving straight flow through the sewers. Gas port coolers, lined with 6 in. high alumina brick, were also used. Filters were installed for all water used for furnace cooling.

The use of double-burnt dolomite and magnesite for bottom making, and the use of all double-burnt dolomite on the banks after each heat has resulted in the lowering of the lost time due to bottom repairs. From October, 1938, to September 21, 1939, inclusive, total lost time for the entire open hearth was as follows:

Number of heats	3144
Time lost due to bottom, bank and tap hole repairs	210 hr.
Average time lost per heat	4 min.
Time lost due to burnouts, furnace repairs, etc.	213 hr.
Average time lost per heat	4.06 min.

Furnace operations are carefully controlled. A laboratory on the open hearth floor affords convenient checking facilities. Flux charge is controlled by hot metal analyses. Carbon is checked by means of a carbometer. A method of slag control is also in use.

Turbo-blowers were installed on all gas producers, and all producer coal is screened, the slack going to the steam plants. The coal used per hour increased, although coal consumption per ton of ingots decreased from over 500 lb. to less than 400 lb. When gas is off for a burnout, oil is used on the furnaces. Roof temperature controls have been applied to the furnaces.

The size of charging boxes was increased by about one-third, replacing the old 20 cu. ft. boxes with a box of 26.6 cu. ft. volume. Old 3-box charging buggies were replaced with new 4-box roller bearing equipment, and charging machines were materially improved.

Ladle cranes were reinforced, and equipped with new improved hoists and bails. Elliptical welded ladles are now used, as well as double ingot buggies with a capacity of six ingots. The use of permanent cast iron hot tops, which can be quickly and easily made ready for the next heat after being used, also keeps brick bats out of the soaking pits, reducing damage to the pit bottoms. A building, containing the special equipment for preparing hot tops for pouring, has been provided, as well as a stripper crane to loosen big-end-up ingots in the moulds.

Oxygen has been piped to the tap holes from a central station, and high pressure air connections provided at each furnace for blowing out ports, tap holes, and holes in furnace bottoms.

Throughout the entire length of the open hearth pit, track has been laid on steel rails embedded in concrete, so that railroad cars can be put into and taken out of the pit at either end.

Faster disposal of refuse is effected by the use of railroad dump cars on the floor, used in connection with large boxes handled by the cranes. Slag is shot from the slag pockets, and brick conveyors speed up the rebuilding.

L. F. REINARTZ: Mr. Danforth has presented an interesting account of the modernization program carried on by many steel plant executives in recent years. It is a foregone conclusion that open hearth furnaces in antiquated plants have not the slightest chance to compete with the furnaces that have been built in recent years. However, it is also true that, in most cases, a modernization program will bring richer returns than a policy of scrapping old furnaces and building new ones, or adding new large furnaces to increase the output of an antiquated shop.

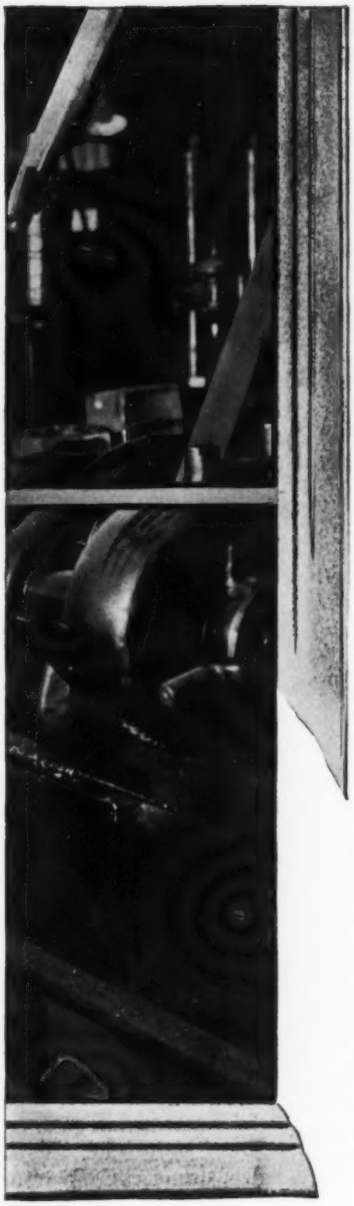
Outstanding examples of modernization have been cited. In our own case, furnaces built between the years 1911 and 1917, and considered in the obsolete group by Mr. Danforth, having an actual tapping capacity not exceeding 75 tons per heat have, over a period of years, been enlarged so as to average 160 tons per heat. This program included the acquisition of a blast furnace plant located in a community twelve miles away. The hot metal is transferred to the open hearth plant in cigar-shaped brick lined steel mixer cars which make the trip to the steel plant in one hour's time.

Stockyard facilities were carefully studied and the following improvements made: an additional overhead crane, heavier stock engine, five-pan instead of four-pan buggies, larger and stronger pans, heavier rails, better arrangement of scrap and pig iron stocks, and installation of roller bearings on charging buggies. Stress has been placed on full loading of all pans. Domestic scrap is either bundled in a baler, or piled and wired securely into bundles suitable for charging.

On the open hearth floor charging machines were

(*Please turn to page 76*)

..."WHEN OUR MACHINES STARTED AT 1:00 P. M.— MAIN FUSES OFTEN BLEW — BUT WE CURED THE TROUBLE BY INSTALLING BUSS FUSES!"



• • • • DO YOU HAVE A SHUTDOWN PROBLEM LIKE THIS ONE DESCRIBED BY MR. HARRY R. TROUT,

Plant Superintendent of Eastern Foundry Company, Boyerton, Pennsylvania:

"During the early part of 1939 we were troubled with our 400 ampere main fuses blowing at 1:00 P. M. when the motors on the machines were started at the same time and caused a momentary heavy inrush of current until the motors came up to speed. These unnecessary shutdowns were an annoyance, caused confusion and were expensive.

"At the suggestion of a BUSS Fuse representative we installed BUSS Super-Lag fuses and since that time have not experienced a single shutdown from this cause."

Eliminate needless expense in your plant, too, by using BUSS Fuses

BUSS Super-Lag fuses don't open needlessly because the Super-Lag Fuse-Link gives them a time-lag that permits harmless overloads, such as encountered by Mr. Trout, to clear themselves without blowing the fuse —and the BUSS Fuse-Case is so designed that it guards against poor contact, link injury and other common causes of fuses opening without good reason.

How to get action!

Simply knowing that BUSS Super-Lag Fuses do save money by preventing needless shutdowns is knowledge —but it isn't action.

But by passing the word along that all purchase and stock records should call for "BUSS Super-Lag Fuses" you have action that begets money saving.

For your own information, or that of others in your organization, send for the interesting booklet—"How to Select Renewable Fuses"—it makes clear why BUSS Super-Lag Fuses give "pocketbook protection" as well as electrical protection. Bussman Mfg. Company, University at Jefferson, St. Louis. Division McGraw Electric Company.

BUSS *Super-Lag* FUSES

WHY BUSS FUSES DON'T BLOW NEEDLESSLY
10 FEATURES in the design of the FUSE-CASE help make it possible..
The SUPER-LAG development in the FUSE-LINK completes the job.

ADVERTISING PAGES REMOVED

(*Continued from page 73*)

rebuilt; a dolomite gun was purchased to speed up bottom-making; sloping backwalls were installed in the open hearth furnaces; basic bricks were used in front-walls, ends and ports. The fuel was changed from producer gas to natural gas or liquid fuel. Oil and gas burner designs were improved and temperature control was installed to regulate checker chamber temperatures. The ends of each hearth were extended making the hearth longer. The width of the hearth was increased 18 in., and the depth of the bath increased by the use of heavier fore-plates.

Gas and air slag pockets were combined into one large pocket which would hold the slag for a full campaign, and would allow rapid removal of slag during rebuilding periods.

Due to water leaks, and inter-changes between producer gas and air valves, Isley stacks and control were installed which eliminated all valves in the flues to the stack and made it possible to add in their places auxiliary checker chambers which increased the regenerative capacity of the furnace by at least 30 per cent. Insulation up to floor level was made as positive as possible. An engineer was kept in constant attendance to improve small defects in design. Bricklayers were very helpful in improving the technique of laying brick in various parts of the furnace.

In the pit it became necessary to install a new 225-ton crane with a very long wheel base, and to strengthen the crane runways. Oval, welded steel ladles were purchased. These ladles were of such a design that the increase in size of heats did not drastically increase the ferro-static pressure of the metal when teemed into the molds.

Suitable chutes and hoppers were installed to help make ladle additions regularly, safely and economically. Such auxiliaries as magnets, large powerful buckets and mold capping cranes were added to decrease delays in the pit. Mold handling and cleaning equipment were improved.

All furnace changes were made during a regular rebuilding period. The usual time to make a complete rebuild varied from four to six weeks.

Very satisfactory results have been shown by following the outlined program. Regular shop fuel records of less than 3,800,000 Btu. per ton have been made month after month. Several furnaces have made more than 10,000 tons per month with a record of 13½ tons per hour on one furnace on a 31 per cent hot metal charge, making practically all low carbon (under 0.08 per cent) heats. Furnace repair costs have been cut in half and operating costs reduced to the point where they compete with the most modern shops.

I believe Mr. Danforth's estimate of expenditures to modernize an open hearth furnace is a little high, as in the case cited, the actual expenditures were less than $150,000 per furnace for the furnace and pit modernization program.

I agree with the statement made that it is possible to charge a large open hearth furnace too rapidly. If the scrap is charged in a number of drags, the flame is given an opportunity to heat the charge throughout. This ultimately facilitates melting of the total charge.

A movable open hearth furnace roof does not appeal to me because, as stated in the paper, construction costs would be increased, and bottom maintenance and structural maintenance costs would be increased with little collateral savings.

Tapered open hearth doorways should help decrease the aggravating delays due to scrap and pig iron damaging sides of frames while charging operations are going on. If such frames will allow the use of larger boxes and they can be accommodated on existing stock buggies, operations will be greatly speeded up.

Mr. Danforth's suggestions regarding pit and mold yard facilities are timely. The best made heats in the open hearth furnace may be ruined by a neglect to follow simple rules of procedure in pit operations. Proper rod assembly, and well made sleeves and stopper heads and nozzles are prerequisites to success. A vertical stopper rod oven of large capacity is a valuable asset to a plant.

Rails, especially under the stripper cranes, should be of heavy construction, and engines should be of ample capacity to haul heats rapidly and smoothly to and from the pits. Deisel locomotives, due to their high availability and low operating cost, are helpful in speeding up open hearth switching operations.

Mold yard facilities, especially if many mold sizes must be used, should be sufficient to expedite changing of molds. There should be at least one drag of molds for each furnace in operation with one or two drags as spares to speed up changes in mold sizes.

Mold spraying or dipping equipment should be easily handled and able to coat molds quickly and efficiently.

In regard to control of open hearth furnaces, we are not yet ready to approve automatic equipment as our furnace crews, we believe, are able to produce very good results with the equipment available. We do believe in reversals being made manually based upon definite temperature differentials in checker chambers. We believe in regulation of the draft in a furnace as well as an air-gas ratio control and a meter showing the Btu. consumption per hour, as well as a cumulative record of fuel consumption. Although we have not used it as yet, we believe a roof temperature control is helpful in the operation of a furnace.

The human element must not be overlooked or neglected. A great deal depends on the skill, interest and enthusiasm of the open hearth supervision and the workmen in making the necessary changes to derive the greatest benefit from a modernization program. Maintenance, service, and operating men by close cooperation and mutual assistance can make an old shop break records unheard of twenty years ago.

Plans, such as have been discussed, usually cannot be carried out in a short time. They present an interesting and valuable program for improving the quality of the steel produced, and reducing the operating cost per furnace in those shops where increased tonnage is not needed. In shops requiring more tonnage it is the easiest and cheapest way to secure at least part of such additional requirements.

FOLLANSBEE STARTS PLANT REBUILDING

▲ United Engineering and Foundry Company has received orders from Follansbee Steel Corporation for two reversing cold mills, one temper pass mill and a tin plate flying shear, for delivery in July.

Follansbee Steel Corporation is a recent reorganization of Follansbee Brothers Company, with W. T. Brownscombe, formerly of McKeesport Tin Plate Company, as president. One of the objects of the reorganization was to permit modernizing of the plant at Follansbee, West Virginia. The company operates two plants, located at Follansbee, West Virginia, and Toronto, Ohio, producing hot rolled sheets and tin plate.

The Follansbee company plans to purchase hot-rolled, pickled strip and reduce it to tin plate gauges on the two new reversing mills. After cleaning, it will be annealed in new, modern gas-fired annealers, temper passed and sheared. From this point on, it will be handled on existing equipment, which will be overhauled and additions made where required. The temper pass mill is wider than the reducing mills, so that it can take the product of an existing cold mill and any wider future mills. After rolling, the finished strip is coiled on a collapsing drum type coilers, from which the coil is removed to shearing lines, where it is side trimmed and cut to length.

The flying shear will be of a reciprocating type with a range of 18 to 40 in. This type of shear produces cut lengths of extreme accuracy over the entire range of lengths at any speed up to the maximum permitted by the reciprocating motion.

GARY PLANT ADDS NEW COKE OVEN BATTERIES

▲ Carnegie-Illinois Steel Corporation has awarded a contract to the Koppers Company to build two new batteries of coke ovens of 71 ovens each at the Gary Works. The 142 new ovens will be Koppers-Becker underjet type. Construction is to be started immediately and the ovens should be completed by the end of this year.

NEW CONTROL HOLDS CONSTANT RATIO

▲ Mixture of air and gas in the proper proportions is assured by the new air-gas "Ratiotrol" manufactured by the North American Manufacturing Company. This control produces an air-gas mixture of constant proportion, making both fluids interdependent while passing through an aspirator and an atmospheric regulator respectively. To insure successful operation of a completed installation, the aspirators possess a measure of flexibility that makes it possible to obtain some corrections for capacities, varying pipe resistances, etc., without altering the installation itself.

The control valve has an adjustable port that can be set to insure effective control of the air over the whole motor operating range together with an external by-pass to furnish air at blower pressure to an auxiliary diaphragm on the atmospheric regulator when the control motor goes to the shut off position.

The force from this diaphragm actually closes off all gas flow to the burners at this point which, among other advantages, eliminates all possible over-riding of temperatures at low temperature settings.

A constant ratio is maintained between the combustion air and the fuel gas as part of the energy in the air stream aspirates the gas so that a fixed relationship is in existence at all times between the quantities of the two fluids flowing.

This control produces a mixture of fuel gas and combustion air in the proper proportions.

DESIGN SHEET LIFTER TO LIFT DOUBLE LOAD

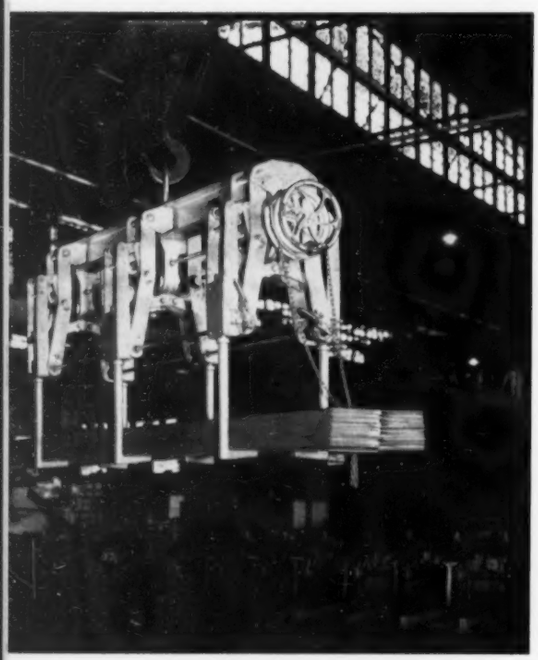
▲ A new style swivel leg sheet lifter especially designed for handling narrow sheet steel has been designed by the Cullen-Friestedt Company. This sheet lifter which lifts two packs at one time, side by side, eliminates damage to edges of sheets and permits closer piling in storage and in loading cars.

The sheet lifter can also handle any single bundles coming within its minimum and maximum opening range. The lifter is lowered over bundles with a minimum amount of space between piles, and with the prongs positioned parallel to the length of the sheets. When lowered to the proper height, the prongs are swiveled 90 degrees, which brings them under the packs. A few turns of the hand wheel or chain wheel closes the lifter to a position where the vertical leg is in contact with the side of the pack and lift is ready to be made.

With a capacity of 7 tons, this lifter has opening range sufficient to handle single packs of sheets varying in width from 15 in. to 30 in., or two packs at one time, side by side, having a total width of not over 30 in. Legs are 22 in. deep and spaced 48 in. apart to correspond to rollers of runout table. The above dimensions can be varied and the lifter can be made with as many legs on each side as necessary to suit requirements. The lifter opening and closing mechanism is actuated by hand wheel or chain and chain wheel through spiral gear reductions fully enclosed and running in oil.

The swivel movement of the legs is made through spiral gears on each side of the carrying legs and is controlled by two levers, one for each side of the lifter and both located at the same end of lifter as operating wheel. All of the legs on each side of the lifter are swiveled simultaneously and lock in either a parallel or right angle position in relation to the length of the sheets.

Capable of lifting two packs at one time, this sheet lifter eliminates damage to edges of sheets.



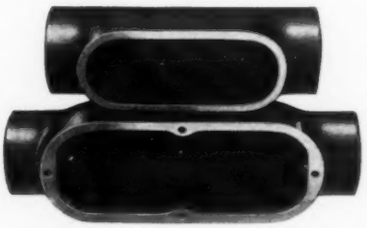
ROLL REPAIR RECORD SET BY ARC-WELDING

▲ When a large steel plant found that its sheet-mill roll frame was badly worn, it was repaired quickly by arc welding. The real problem was to get it done without stopping production of vital materials, so it was done during the Christmas period. The mill was shut down when Friday night's turn stopped and then dismantled, the 41,000 lb. cast-steel housing being delivered to the machine shop of the Canadian Westinghouse Company at 10 A.M. on Saturday, December 23. Building up the surface to permit both the feet and bearing recess to be machined to the original contours and size required 405 cu. in. of weld metal weighing 115 lb. This was obtained from 160 lb. of ¼ in. down-hand welding electrodes, thus showing an over all deposit efficiency of 72 per cent of the electrode used with the Flexarc welders. Welding commenced at 11 A.M. and continued by means of relief operators without a moment's interruption, except for two changes of position, until 8 A.M. on Sunday, December 24, when it was handed over to the machine shop staff with the welding work completed.

NEW CONDULETS HAVE WIDER WIRING SPACE

▲ For use where sizes of conductors, number of splices, or tapping and pulling requirements necessitate more room than found in some types of condulets, Crouse-Hinds Company has developed a new series of condulets. These new condulets, known as: "Form 8 Series Condulets," have wiring chambers wider and longer than other condulets of comparable sizes. The construction of these condulets also provides an extra wide surface for a gasket between the condulet and cover.

Blank sheet steel and cast alloy covers are made for all sizes. The covers are especially suited to corrosive atmospheric conditions. Additional strength and wiring space are provided through the domed shape cover.



These new condulets possess wiring chambers much wider and longer than ordinary condulets.

Blank bakelite covers may be drilled, where more than five wire holes are required, or to meet other special requirements. Bakelite covers are also made with two wire holes and three knockouts making them suitable for two, three, four, or five wires.

VERNIER CONTROL FOR SPEED TRANSMISSION

▲ A recent announcement was made by the Link-Belt Company of the availability of all sizes of their gear variable speed transmission with vernier control, for installations where extremely fine control of speed changes is required. This vernier control

can be supplied with either one of two ratios: 7½ to 1 or 30 to 1, and is equipped with two hand wheels. One is for direct control; the secondary, or vernier type control hand wheel will provide either 30 turns or 7½ turns to one of the direct wheel, depending upon which ratio of worm-gear reduction set is furnished.

As vernier control is said to provide the fine sensitivity required for true micrometer adjustments of speed, the manufacturers are particularly recommending is for such services as: synchronizing the speeds of two machines; justifying for shrinkage and expansion; controlling feeders; on weighing operations; obtaining exact register; or wherever the uniformity of a product can be assured by such close speed regulation.

NEW ROTOR ASSURES LONGER MOTOR LIFE

▲ Offering the advantage of longer motor life with less maintenance, a new type rotor construction announced by the General Electric Company makes possible the use of cast-aluminum rotors in the larger sizes of double squirrel-cage motors for high-starting-torque, low-starting-current service. Called the "Valv-amp" rotor, it makes use of a unique shape of rotor slot and a special method of assembling rotor punchings to control the flow of starting current. As a result, without the use of a switch or other moving parts, current is permitted to flow in the outer squirrel-cage when the motor is started, thus producing high-starting torque. Then, when the motor comes up to speed, current is allowed to flow through the entire rotor "winding," resulting in excellent running characteristics.

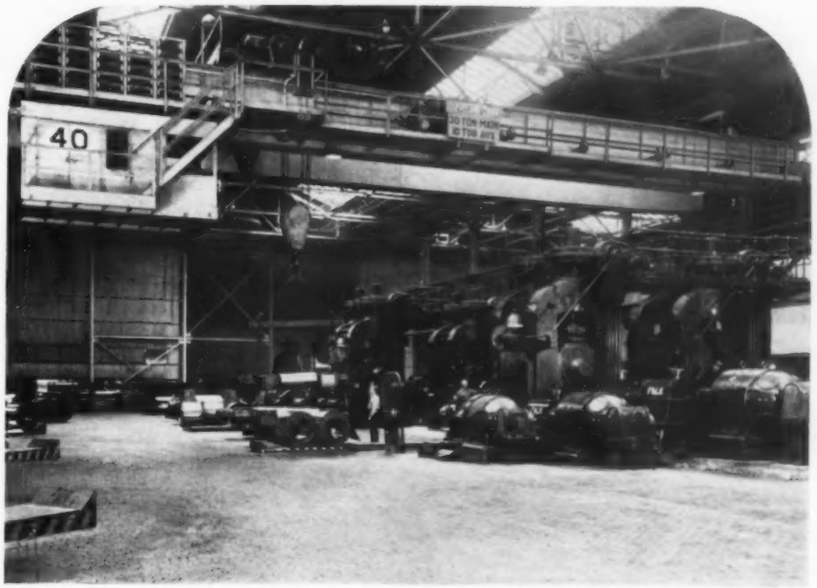
Of the two conventional methods of double-squirrel-cage rotor construction, *i.e.*, casting the conductor bars and short-circuiting rings integral or joining them by brazing, the former method is by far the more satisfactory because it is a simpler operation, with smaller chance for human error, and results in a more compact, uniform product. However, until this development, it has not been practicable to cast double-squirrel-cage rotors in the larger sizes.

The development, however, allows the construction of larger cast-rotor motors which inherently combine the advantages of the double-squirrel-cage motor, such as high-starting torque, low-starting current, and excellent running characteristics, with advantages of the conventional cast-rotor motor—simplicity of construction, long motor life, little maintenance, and permanence of electrical characteristics.

RESEARCH GIVES NEW VULCANIZING PROCESS

▲ After several years of research and experimentation, the Hewitt Rubber Corporation has developed a method for bonding soft rubber and neoprene to steel and aluminum by hot vulcanization which results in exceptionally high adhesion strength between the rubber and the metal with remarkably good aging qualities.

The processes employed for attach-



30 ton, 80'—0" span Cleveland all-welded Crane with 10 ton auxiliary hoist in a tinplate mill.

THEY BUY 5 TO 20 AT A TIME

When mills buy Cleveland all-welded cranes in lots of 5, 10, and 20 at a time, they must have features that are outstanding.

Cleveland Cranes are different from all other cranes because all parts are welded including the girders. There is no sag from rivet slippage to cause misalignment and abnormal wear. Because of the special shoulder construction girders remain square with the end trucks for the life of the crane.

Investigate Cleveland all-welded steel mill cranes.

THE CLEVELAND CRANE & ENGINEERING CO.
Wickliffe, Ohio

CLEVELAND CRANES
ALL-WELDED OVERHEAD TRAVELING CRANES
Other products: CLEVELAND TRAMRAIL and STEELWELD MACHINERY

ing rubber to metal are of a chemical nature. By means of this special chemical treatment the composition of the rubber is modified in such a manner that it will attach itself integrally to the metal and still retain its capacity to vulcanize itself to the outer rubber layer.

This process is called "Dura-Bond" and is based upon newly discovered methods of attaching soft rubber and neoprene directly to steel and other metals, which results in an adhesion strength of 500 to 750 lb. per sq. in.

The use of rubber-metal vulcanized combinations in industry is rapidly increasing. These products combine the abrasion and corrosion resistance as well as the sound-damping properties of rubber with the strength and rigidity of metal.

With reference to the heat conditions for the process, the company limits its recommendations to temperatures up to 200 degrees F. Chemists and researchers are continuing their work on this problem in an endeavor to extend the range of high temperature service conditions to at least 250 degrees F.

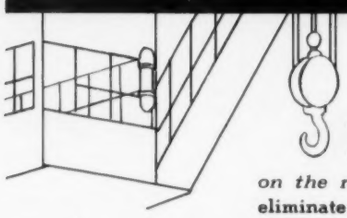
TELEPHONE BOOTH FOR NOISY LOCATIONS

▲ A new model of acoustical telephone booth was recently announced by the acoustic division of the Burgess Battery Company. The new booth is designed to provide a zone of quiet for telephones used in steel plants, power houses, and other noisy industrial locations.

The new booth has no doors and is lined with a heavy layer of sound absorbing material protected by perforated steel facing developed by the Burgess laboratories. Owing to its patented acoustical construction, plant noises and disturbances are absorbed so completely by the lining that telephone calls can be made without interruption from these causes. Conversations in ordinary tones are not heard outside the booth, thus assuring privacy. Added advantages are ample ventilation, due to its open construc-

This new telephone booth is designed to provide a quiet communication zone in steel plants.

Now ...Crane Signal Equipment Shows Condition of Each Crane Prevents accidents—costs little

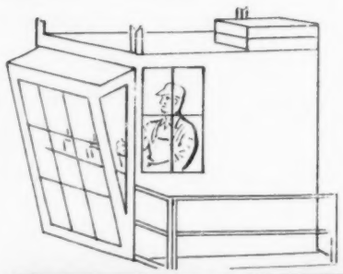


Lintern

BY providing a signal for all cranemen showing the condition of *every crane on the runway,* Lintern Glowlite Crane Signals eliminate guesswork and carelessness, save life and property.

The signal assembly (Glowlites) is mounted outside the cab where it is most easily seen from other cranes on the runway When light is red, the crane is *not* to be moved under any consideration; when green, the crane is operating and can be moved. No signal (lamp failure) stands for a red signal until investigated.

Equipment consists of the popular Glowlites and No. 580 EM Safety Switch. The switch, with red and green signal indication, is located in the cab within easy reach of operator.



Lamps in the switch are connected in series with the respective lamps in the signal, so the craneman has a positive indication *inside* the cab of whichever signal is showing.

This signal equipment is paying splendid dividends in safety and operating efficiency. Many companies are equipping all their cranes. Send for details and estimate of cost.

THE LINTERN CORPORATION
7960 LORAIN AVENUE • CLEVELAND, OHIO

tion, and freedom from door troubles.

The exterior walls are made of heavy gauge, black finished steel, and interior walls are finished in gray. It is furnished complete with metal shelf for telephone, a small panel for the ringer box, and pull-chain overhead light. Overall dimensions are as follows: Height, 79¾ in.; width, 31 in.; and depth, 38 in. Front opening is 24 in. wide and 76 in. high. The net weight is approximately 275 lb.

STORAGE BATTERY HAS INCREASED CAPACITY

▲ A new steel-alkaline storage battery cell which provides 33⅓ per cent more electrical energy without any increase in floor space, has been announced by the Edison Storage Battery Division of Thomas A. Edison, Inc. This battery, which is of the "D-type", is particularly useful for large heavy-duty trucks, for trucks operating 24 hours a day held to one battery change, and for trucks operating through narrow clearances.

This steel-alkaline battery operates on the principle formulated by Thomas A. Edison. All the advantages of this principle, including a 3 to 5 times longer life, lighter weight, and freedom from trouble, are inherent in the new type cell.

BIN WALL CAPS OF NON-MAGNETIC STEEL

▲ Developed for use in its own six foundries, but now available for similar use in other plants, are the new bin wall caps made by the American Manganese Steel Division of the American Brake Shoe and Foundry Company.

These caps are cast of 13 per cent manganese steel, the toughest steel known, which is not only highly resistant to impacts, but non-magnetic as well. The caps are applied to the wall tops of bins used to store ferrous melting stocks, such as steel scrap, which is customarily handled in and out of bins with lifting magnets. The non-magnetic character of austenitic manganese steel prevents any fouling by a magnet and the possibility of pulling the caps loose.

In handling any material, magnetic or otherwise, these caps, because of their great shock resistance, resist breakage from the inevitable banging against them of either grab-buckets or magnets.

The individual castings, made with inner reinforcing members, are welded together into units before application, such as tees, ells, and long straight pieces.

NEW FACESHIELD FOR SAFETY FROM SPARKS

▲ A new line of faceshields has been developed by the Mine Safety Appliances Company. Intended for use on jobs where goggles are not absolutely required, yet protection to the face desirable, these faceshields are said to afford comfortable protection against hot sparks, chemical splashes, flying grit and dust, etc., and are available

READY NOW . . .
Useful Information on Flexible Couplings

If you are interested in the most efficient means of guarding against the effects of misalignment of connected shafts, you will find much helpful information in our new catalog of Farrel Gearflex Couplings.

This catalog, No. 443, explains the functions of a flexible coupling and describes how the wide range of types and sizes of Gearflex Couplings meets the requirements for practically any coupling application. Details of design, construction and application are described and fully illustrated by a series of 52 halftone plates and 21 diagrams. Tables of ratings, dimensions and weights covering seven types of flexible couplings are given, and their applications listed.

The catalog also contains full information on service factors and their use, the application of service factors in selecting flexible couplings, information necessary in ordering, etc.

Complimentary copies of Farrel Gearflex Coupling Catalog No. 443 will be sent to plant executives and engineers who will write on their company letterhead to the address below.

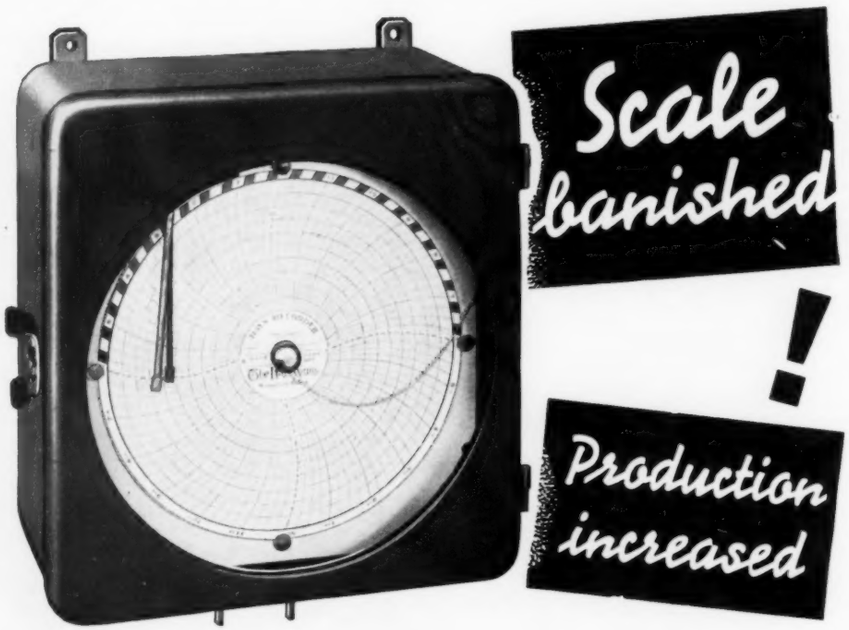
FARREL-BIRMINGHAM COMPANY, INC
366 VULCAN STREET BUFFALO, N. Y

FARREL SYKES GEARS
The Gear with a Backbone

in three models: without sparkshield, with semi-sparkshield, and with full sparkshield.

Pre-formed headgear, which conforms to the natural contours of the back of the wearer's head, as distinguished from ordinary oval "hatband" construction, is a feature stressed by the manufacturer, as is the headgear's center top strap, which supports the light weight of the shield without pressure on sides of head—the three-way, full headgear adjustment, finger control of friction adjustment permitting easy visor movement, and the aluminum binding of visor edge, which extends around the entire edge and greatly increases durability.

The visor, which may be pushed upward and back on top of the head at will, is stated to be made of the best commercially available plastic in 4 in., 6 in. and 8 in. sizes, in green as well as clear. The headgear is constructed of high-quality moisture-resistant fibre, and sweatbands are genuine leather.



A SLAB MILL had serious trouble with a dense scale that the high pressure sprays could not knock off. A Hays Supersensitive OT Draft Recorder was installed which revealed a large amount of oxygen being fed into the furnace during the charging period. The pressure was adjusted to plus 5/100 in., water-scale was practically eliminated and production noticeably increased.

Two draft values, two pressure values, two differential values, or a combination of any two of these three values may be recorded. These "OT" Recorders are sensitive enough to register accurately increments of .0025 in. water yet are husky enough to stand up under the jars and dirt of steel mill operation. Write to 955 Eighth Ave., Michigan City, Ind. for Bulletin 37-232.

The HAYS CORPORATION
SINCE 1901
COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A

ARMCO GIVES LICENSE FOR ANNEALING COVER

▲ The Wean Engineering Company, Inc., has been licensed by the American Rolling Mill Company to have manufactured and sell corrugated inner covers under United States patents Nos. 2,069,768, 2,074,093, 2,078,718, and 2,105,750; Canadian patents Nos. 367,066, 369,348, and 367,067; and other pending United States and Canadian patent applications.

Consideration is being given to having various fabricators in the United States and Canada do the manufacturing for The Wean Engineering Company, Inc., under this license, but no contract arrangements have been concluded yet.

ALGOMA STEEL BUYS SHEET ROLLING MILL

▲ Algoma Steel Corporation, Ltd., of Canada has placed an order for a three-high break down sheet mill. The mill will be engineered by Lewis Foundry and Machine Division of Blaw-Knox Company, and built by Canada Iron Foundries, Ltd., with which Lewis Foundry and Machine has a manufacturing arrangement.

The Lewis company is now producing at its local plant a similar sheet mill recently ordered by an American steel company.

NEW LITERATURE

▲ Farrel-Birmingham Company, Inc., recently published a new illustrated catalogue on "Farrel Gearflex Couplings." This catalogue explains the function of a flexible coupling and describes how Farrel Gearflex Couplings compensate for parallel or angular misalignment or a combination of

both, illustrating the details of design and construction. It gives the applications, ratings, dimensions and weights of the various types of flexible couplings manufactured by this company.

▲ General Electric Company has available a new bulletin on the selection of arc-welding electrodes. Prepared as a guide for the proper selection of electrodes, the publication also gives important suggestions on welding technique with different types of electrodes and presents some of the factors influencing their choice. Complete descriptions are given of the twenty types of General Electric electrodes, their applications, sizes, recommended currents, arc-voltages, and identification.

Copies of this Catalogue GEA-1546 will be sent upon request by writing to the General Electric Company, Schenectady, New York.

▲ Norton Company has made available a pocket-size handbook on the subject of: "Facts About Grinding Wheels." This book is divided into three parts: Part I—Grinding and Grinding Wheels; Part II—Reference Tables, Wheel Selection; and Part III—General Grinding Information. Readers who would like to have a copy of this catalogue should direct inquiries to the Norton Company, Worcester, Massachusetts.

▲ The 1940 edition of *Cast Metals Handbook* presents condensed authoritative data on cast metals, which should prove of great value to engineers, designers and users of castings. The book deals with cast steel, cast iron, malleable iron and non-ferrous metals, and the material, covering the metallurgy, properties, specifications and testing of these metals, has been prepared by committees composed of individuals well qualified for the work. The design of castings is also considered.

The handbook is published by the American Foundrymen's Association, 222 West Adams Street, Chicago, Illinois.

▲ Link-Belt Company has published in a pocket-size digest form a 64-page book of selected editorials from *Link-Belt News*, its monthly publication. These editorials of broad general interest and mostly of a philosophical nature were written by prominent authors and first appeared in well-known magazines and newspapers.

Upon request a copy will be sent free to any interested reader. Address: Link-Belt Company, 307 North Michigan Avenue, Chicago, Illinois.

▲ Allis-Chalmers Manufacturing Company has prepared a handy 32-page 1940 Directory, listing in numerical order more than 350 separate bulletins and other engineering aids now available from the factory on request. These include 280 different items on power, electrical and industrial machines produced by the company; about 40 instruction books and repair part bulletins, and 38 catalogues and folders on other subjects.

The new directory, which also lists 1,610 different and widely diversified products of this company, may be obtained by writing the Allis-Chalmers Manufacturing Company, in Milwaukee, Wisconsin.

BURT *Free-Flow Fan* VENTILATORS

Move Air Out Quickly

In steel mills it is often necessary to exhaust large volumes of hot or fume-laden air from a particular locality faster than can be done effectively with gravity ventilators. Also, due to varying weather conditions, gravity ventilators may fail to function uniformly.

In these situations Burt Free-Flow Fan Ventilators find particular application. Their capacity is five times that of gravity ventilators of the same size, and they operate at top efficiency at all seasons in all weathers.

These sturdy heavy-duty units range in size from 12-inch to 96-inch with free air deliveries from 1200 cfm to 100,000 cfm.

Scientific construction provides for continuous free flow of air upward and outward with minimum resistance and without generating turbulence. Motors are protected against high ambient heat and corrosive vapors.

Burt Engineers are glad to render assistance without charge or obligation.

The BURT Manufacturing Co.

ROOF VENTILATORS — OIL FILTERS

EXHAUST HEADS

950 SO. HIGH ST., AKRON, OHIO

ITEMS OF INTEREST

H. G. R. Bennett, assistant general superintendent of the Carnegie-Illinois Steel Corporation at Duquesne, Pennsylvania, since 1933, has been appointed to the staff of the corporation's chief engineer at Pittsburgh. First employed by a subsidiary of United States Steel Corporation in 1901, Mr. Bennett's many years' experience in rolling mill engineering qualified him for his new position. He joined the former Carnegie Steel Company at Youngstown in 1907, and subsequently worked for the company at Milwaukee, Wisconsin. He returned to Youngstown as a special engineer in 1908 and in 1916 became master mechanic. He was appointed assistant superintendent of bar mills at Youngstown in 1925, and was transferred to the Duquesne Works as assistant general superintendent May 1, 1933.

Mr. Bennett has been an Active Member of the Association since 1914, and has served both as president and a director.

Walter A. Jayme, general superintendent of the Wood Works of the Carnegie-Illinois Steel Corporation, McKeesport, Pennsylvania, has been named assistant general superintendent at the Duquesne Works succeeding H. G. R. Bennett. Mr. Jayme was graduated from Massachusetts Institute of Technology and began his business career as a metallurgist in 1921. He soon became a specialist in steel alloys and was associated with several alloy producing steel companies before joining the metallurgical division of Carnegie-Illinois in November, 1935. He became manager of the alloy division in June, 1936, and was appointed general superintendent of Wood Works in March, 1937.

Carl M. Nystrom has been appointed general superintendent of the Wood Works of the Carnegie-Illinois Steel Corporation at McKeesport, Pennsylvania. Mr. Nystrom, a native of McKeesport, has been employed at Wood Works during his entire industrial career. He began as a metallographist in January, 1926. He was appointed foreman of the chrome polishing and inspection department on December 1, 1928. He received metallurgical training at the Carnegie Institute of Technology and was appointed assistant general superintendent of the plant in March, 1937. In his former position, Mr. Nystrom also served as superintendent of industrial relations and director of training.

Robert A. Peterson has been appointed superintendent of hot mills at the Cuyahoga Works of the American Steel and Wire Company, a unit of the United States Steel Corporation at Cleveland, Ohio. Mr. Peterson is being transferred from the position of a department superintendent at the Gary Works of the Carnegie-Illinois Steel Corporation, another subsidiary of United States Steel Corporation. He had previously been employed by the American Steel and Wire Company.

Paul Lindberg, until recently superintendent of rolling mills of the Steel and Tube Division, Timken Roller Bearing Company, Canton, Ohio, has been appointed superintendent of rolling mills of the steel division of Copperweld Steel Company, Warren, Ohio. Mr. Lindberg began steel mill work as a roller in Swedish steel mills. His experience consists of over 42 years in steel mill work in the capacity of roller to superintendent of rolling mills. He first worked in this country for the Carnegie-Illinois Steel Corporation at the Duquesne, Pennsylvania, and Youngstown, Ohio, plants, subsequently he was roller, foreman and assistant in charge of rolling for the United Alloy Steel Corporation (now a unit of the Republic Steel Corporation).

H. M. Pendleton, one of the pioneer employees of the National Tube Company, McKeesport, Pennsylvania, retired from

(*Please turn to page 90*)

H. G. R. BENNETT

WALTER A. JAYME

CARL M. NYSTROM

TEN REASONS WHY

you should use the original

ROCKBESTOS A.V.C. WIRE AND CABLE

1 HEATPROOF
Because Rockbestos insulation won't dry out, become brittle, flake or crack to open paths for current leakage and moisture.

2 FIREPROOF
Because Rockbestos A.V.C. Wire has laminated insulation of felted asbestos, varnished cambric and asbestos braid that won't burn or support flame even under an arc.

3 PERMANENT
Because the asbestos in Rockbestos insulation won't deteriorate under heat or with age and is always "as good as new."

4 REDUCES MAINTENANCE EXPENSE
Because Rockbestos heatproof and fireproof qualities give you long-term service and make periodic replacement unnecessary.

5 RESISTS HEAT AND VIBRATION
Because heat can't dry out or crack the Rockbestos insulation, vibration doesn't get a chance to open it up and shake it loose.

6 SAVES WORK
Because Rockbestos stops the merry-go-round of failures and replacements in hot-spots where ordinary wire has a short life.

7 OIL, GREASE AND MOISTURE RESISTANT
Because Rockbestos A.V.C. won't rot or swell due to oil, grease or corrosive fumes and has ample moisture resistance.

8 HIGH OVERLOAD CAPACITY
Because copper heating won't break down or deteriorate the insulation, Rockbestos gives you greater carrying capacity.

9 PERMANENTLY FLEXIBLE
Because asbestos never loses its original characteristics, Rockbestos A.V.C. Wire and Cable doesn't get hard, stiff or crystallize.

10 LONG SERVICE
Because country-wide users testify that Rockbestos Wires and Cables have been giving failure-free service ever since we designed them twelve years ago. Names in your locality furnished on request.

For your requirements the Rockbestos line contains the most complete assortment of heat resisting wires, cables and cords available, in either of the widely used Rockbestos A.V.C. or All-Asbestos constructions. More than fifty standard wires to draw upon, and a research department which is always ready to design a "special" if you need one. For our No. 10-E Catalog write to Rockbestos Products Corporation, 948 Nicoll St., New Haven, Conn., "Headquarters for Heat-Resisting Wires," or get in touch with our nearest branch office.

Also refer to Electrical Contracting and Electrical World Buyer's Reference Editions.

New York Buffalo Cleveland Detroit Chicago
Pittsburgh St. Louis Los Angeles San Francisco Portland, Ore. Seattle

active duty January 31, 1940. Mr. Pendleton was with the company for 40 years, the last 33 as superintendent of the skelp mills. He began his long term of service with National Tube Company as a laborer and served as a roller in the converting mill and various other plants of the company until 1906 when he was appointed superintendent of the skelp mills. Serving as a corporal in the Spanish-American War, Mr. Pendleton was the first American officer to land on enemy soil in Porto Rico.

Mr. Pendleton has been an Active Member of the Association of Iron and Steel Engineers since 1916.

H. P. Ackerman has been given the entire steel industry as his territory to cover for the valve division of the American Car and Foundry Company of New York, New York. Born in Homestead, Pennsylvania, in 1898, Mr. Ackerman attended high school in Homestead and in Denver, Colorado. He later attended the University of Colorado. In 1922 he went to work with the Homestead Valve Manufacturing Company, where he held the title of eastern sales manager for twelve years. In 1934 he became affiliated with the valve division of the American Car and Foundry Company as a sales engineer.

Mr. Ackerman will maintain his headquarters at 30 Church Street, New York City.

H. P. ACKERMAN

R. C. Norberg, vice-president and general manager of the Electric Storage Battery Company, Philadelphia, Pennsylvania, has been elected president and general manager succeeding John R. Williams, who recently retired from the presidency. Mr. Norberg was born in Sweden and received his technical education at the Royal Technical Institute in Stockholm, graduating in 1902 as an electrical engineer. In 1903, Mr. Norberg came to America and became associated with the Electric Storage Battery Company, where he was an engineer. In 1932, he was called to Philadelphia to become vice-president and general manager, holding this title until his recent election.

R. C. NORBERG

Sidney D. Williams was appointed vice-president in charge of sales for the Copperweld Steel Company's new steel division at Warren, Ohio. Mr. Williams was graduated from Lehigh University in 1913 with the degree of metallurgical engineer. From 1913 to 1918 he worked in various departments of the Homestead steel works of the former Carnegie Steel Company. After serving in the naval flying corps during the World War, he served respectively as superintendent of the open hearth department of the Central Iron and Steel Company, Harrisburg, Pennsylvania, superintendent of the open hearth department and chief metallurgist of the Pittsburgh Crucible Steel Company, Midland, Pennsylvania.

From 1926 to 1940 he has been, respectively, metallurgical sales engineer, assistant director of sales, manager of tube sales and director of sales for the Steel and Tube Division of the Timken Roller Bearing Company, Canton, Ohio.

R. W. H. Atcherson was appointed superintendent of the salvage department at the Carnegie-Illinois Steel Corporation, Gary, Indiana. Mr. Atcherson has been employed in the steel industry for 38 years. His first position was that of a burden clerk at the Bellaire works of the Carnegie Steel Company in 1902. He served in a number of plant supervisory capacities with this company until 1918 when he entered the employ of the Inland Steel Company at Indiana Harbor. Leaving this company in 1922 to become assistant superintendent of open hearth furnaces at Gary works, Mr. Atcherson successively served as assistant superintendent of blast furnaces and superintendent of blast furnaces. In 1929 he was given the post of special engineer and remained in this capacity until the present time.

M. H. Kuhl was appointed assistant manager of the industrial division of the Timken Roller Bearing Company, succeeding S. D. Partridge who recently became manager of the industrial division. Mr. Kuhl, a graduate from the University of Illinois, joined the company in 1926. He has been active in the sales department of the industrial division since that time as sales engineer and district manager.

P. J. Reeves, formerly manager of the Los Angeles office of the Timken Roller Bearing Company, has been transferred to the home office to engage in special sales work. Mr. Reeves, who has been with the Timken company for eleven years, is a graduate of Carnegie Institute of Technology.

S. T. Salvage has been named manager of the Los Angeles office of the Timken Roller Bearing Company, succeeding P. J. Reeves. Mr. Salvage, who is being promoted from the company's sales engineering staff, is a graduate of Stetson University and has been with the company for seven years.

Richard S. Hayes has been appointed advertising manager for Okonite Company of Passaic, New Jersey. Mr. Hayes, who is a graduate of Princeton University, joined the company in 1925. After

2½ years in the factory, he was appointed to the power and light division of the sales department working out of the Chicago office. In 1936 he was transferred to the executive office at Passaic to handle various sales promotion activities.

T. J. Kauffeld, who has been since October, 1936, with the Alfa Laval Company, Ltd., of London, England, is now located in the United States. Mr. Kauffeld, at the present, is maintaining headquarters in the Beaux Arts Building, 307 East 44th Street, New York, New York.

Born in 1902, in New York City, Mr. Kauffeld was educated in the public schools of that city and subsequently entered Stevens Institute of Technology. He was graduated from that school, in 1924, with a degree of mechanical engineer, and became affiliated with Walter Kidde and Company, Inc., as an engineer. In May, 1925, he was transferred to the company's office in Hamburg, Germany as engineer, where he was engaged in engineering design and sales promotion. In January, 1927, he became associated with the De Laval Separator Company in New York City, having returned to this country in November, 1926. After a short period he was appointed special representative for the De Laval Separator Company, and was transferred to Pittsburgh, where he was located for several years.

In October, 1936, Mr. Kauffeld left the United States again for England to act as consultant to the Alfa Laval Company, Ltd. While he was in England, Mr. Kauffeld was offered the position of chairman of the board and managing director of a concern known as Inter-Continental Engineering Company, Ltd. He held the latter position in addition to his duties with the Alfa Laval Company, Ltd.

T. J. KAUFFELD

David W. Thomas was appointed manager of sales, tin mill products of the Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania. Mr. Thomas has been identified with the steel business for practically his entire business experience, having started in 1913 in the accounting department of the American Sheet and Tin Plate Company at Pittsburgh.

In 1917, Mr. Thomas joined the operating department of the Bethlehem Steel Company at Sparrows Point, Maryland. Leaving this plant for the duration of the World War, he returned in 1919 to the Bethlehem plant of the same company where he was located in the operating department. He advanced through various positions in operating, order, schedule, and sales departments of that organization, with most of his activity being centered in the sheet and tin plate sales departments. He left this work to take up his new position with the Jones and Laughlin Steel Corporation.

Maurice E. O'Brien was appointed as an assistant vice-president of the Inland Steel Company, Indiana Harbor, Indiana. Mr. O'Brien will manage the sales of carbon steel bars and billets, a position he has held since 1936. He became affiliated with Inland Steel Company's sales department in 1934, prior to which time he was associated with the Illinois Steel Company.

Obituary

Edward Kieft, 58, chief fuel and power engineer, at Gary Works of Carnegie-Illinois Steel Corp. for more than 20 years, died recently. Mr. Kieft was born in the Netherlands and obtained his technical education in Europe. His first business connection in this country was as an electrical engineer at the International Harvester Company. He became associated with the old Illinois Steel Company in Gary in 1913, remaining with that organization until his death. Though Mr. Kieft was nominally in the fuel and power department, his knowledge of mathematics was applied in all branches of operations, particularly with reference to problems relating to fuel and power efficiency, rolling mill operations and maintenance of plant heat and power balances. He was a member of the American Association for the Advancement of Science and of the Association of Iron and Steel Engineers.

Mr. Kieft has been a liberal contributor to the editorial columns of the IRON AND STEEL ENGINEER.

James E. Jones died recently at his home in Chicago, Illinois, at the age of 83 years. Mr. Jones was formerly chief roll designer for 26 years at the former Illinois Steel Company's South Works. For the past nine years he has been roll consultant with the Continental Roll and Steel Foundry Company, East Chicago, Indiana.

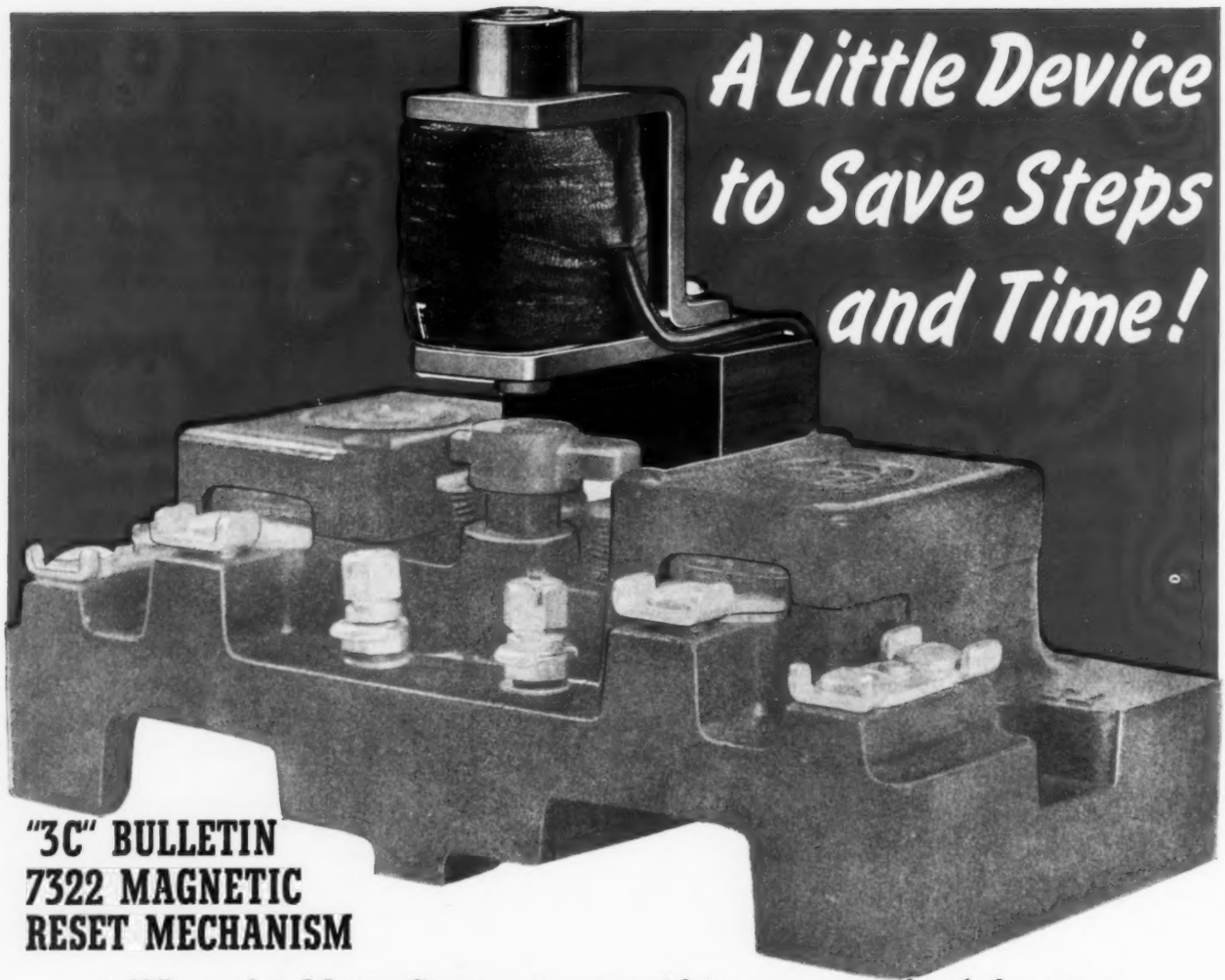
T. H. Heacock, 72, one of the organizers of the Superior Sheet Steel Company, died recently in Canton, Ohio. Mr. Heacock, who has been chief engineer of the Superior Sheet Steel Company, went to Canton from New York state where he had been active in the steel business. His first position in Canton was master mechanic at the former Canton Sheet Steel Company. When the Canton steel leaders formed the Superior Sheet Steel Company, Mr. Heacock joined in the organization and helped supervise construction of the plant.

In 1929 he went to Kokomo, Indiana, to supervise the work of rebuilding the Continental Steel Corporation's plant. Upon completion of this project he returned to the Superior plant at Louisville, Ohio, where he held the position of chief engineer.

ERRATA

In the tabulation of "Electric Motors over 300 Horsepower Applied to Main Roll Drives in the Iron and Steel and Allied Industries during the Year 1939" published on page 70 of the January issue of the IRON AND STEEL ENGINEER, motor number 12 (500 hp., 300–900 rpm., 250 volts, dic.) should be listed as manufactured by the General Electric Company.

Also motor numbers 62 and 63 should be listed as synchronous and not squirrel cage motors.



"3C" BULLETIN 7322 MAGNETIC RESET MECHANISM

When the Motor Starter is not within easy reach of the operator, and the Overload Relay trips, the operator has to walk to the Starter and press the RE-SET button before the Motor will start.

This little Magnetic Reset Mechanism, when applied to Clark Starters equipped with "3C" Bulletin 7322 Thermal Overload Relays, permits the operator to reset the Overload without leaving his position.

Momentary depression of a Push Button causes this Magnetic Reset Mechanism to function.

It's as handy as another pair of legs, and saves plenty of time.

Easy to install, too, and simple in operation. Just push a button momentarily, and this little gadget really goes to town!

For your convenience, our nearest office will give you details.

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THE CLARK CONTROLLER CO.

1146 EAST 152ND ST. CLEVELAND, OHIO